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JSC-08662

SKYLAB MISSION REPORT
SECOND VISIT

National Aeronautics and Space Administration

LYNDON B. JOHNSON SPACE CENTER

Houston, Texas

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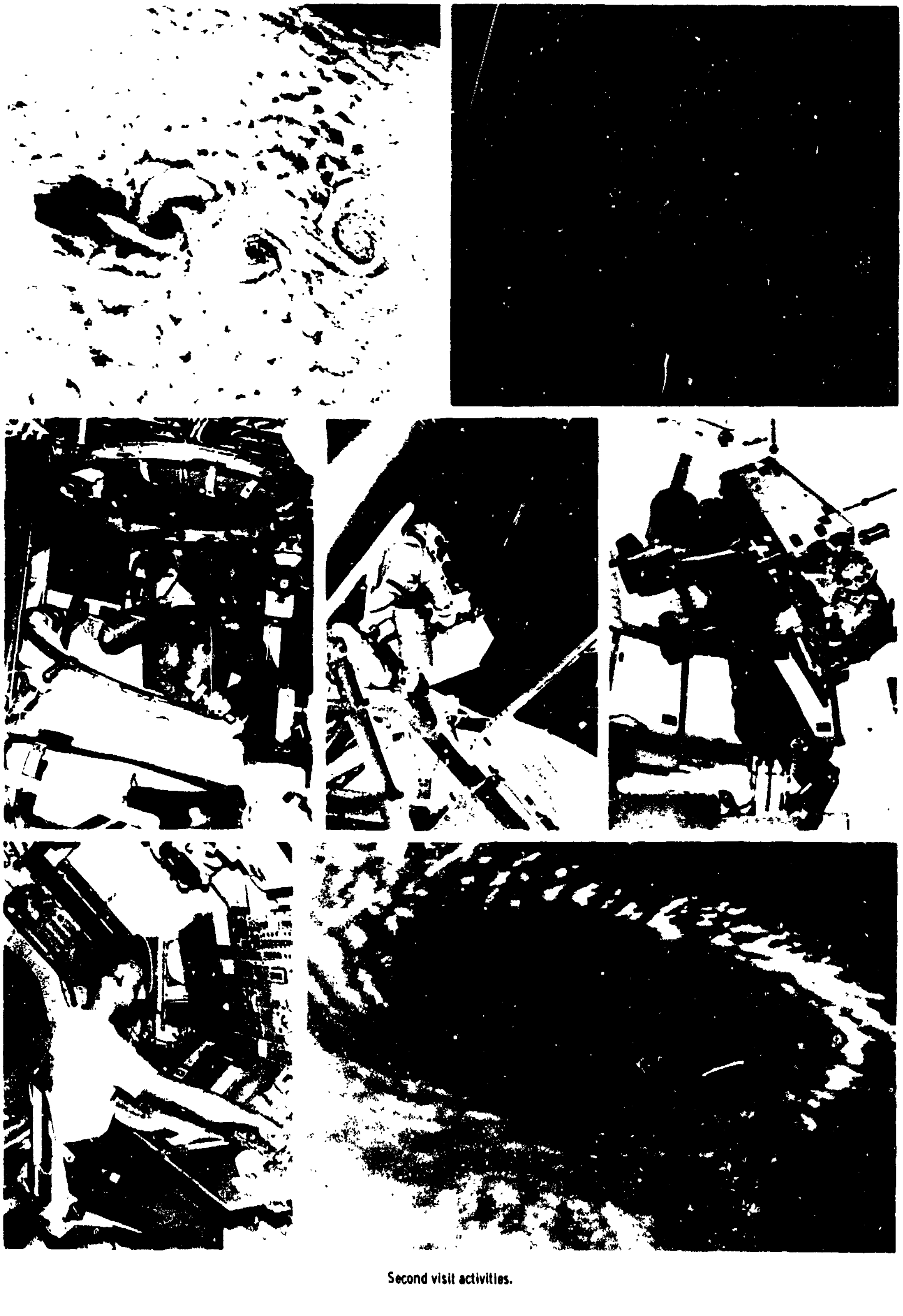
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS
January 1974



Second visit activities.

FORWARD

The Skylab program was established to determine man's ability to live and work in space for extended periods; to determine and evaluate man's physiological responses and aptitudes in the space environment and his postflight adaptation to the terrestrial environment; to extend the science of solar astronomy beyond the limits of earth-based observations; to develop improved techniques for surveying earth resources from space; and to expand the knowledge in a variety of other scientific and technological regimes.

The program activity was planned for four distinct phases of operation:

a. The placement of a Saturn Workshop into earth orbit;

b. The first visit, intended for a period of 28 days;

c. The second visit, intended for a period of 56 days (extended to 59 days); and

d. The third visit, also intended for a period of 56 days, but now planned for a period of 84 days.

This report constitutes the Johnson Space Center's evaluation of the second visit. The report contains the information available 30 days after the completion of the first manned visit.

A Unified Skylab Mission Evaluation Report is planned to be published by NASA Headquarters after completion of the third visit.

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1.0 INTRODUCTION

This report contains an evaluation of the operational and engineering aspects of the second visit and includes the performance of experiment hardware that is under Johnson Space Center management; the crew's evaluation of the visit; and other visit-related items of interest such as medical aspects and hardware anomalies. Scientific results will be reported in accordance with reference 1. Launch vehicle performance will be reported in volume III of the Unified Skylab Mission Evaluation Report. The command and service module consisted of basic hardware developed for the Apollo program and is described in reference 2.

The International System of Units (SI) is used in this report. Unless otherwise specified, time is expressed as Greenwich mean time (G.m.t.) in hours, minutes, and seconds, or in hours and minutes.

2.0 SUMMARY

The second visit space vehicle was launched at 11:10:50.5 G.m.t. (7:10:50.5 a.m. e.d.t.) on July 28, 1973 (first visit day) from Launch Complex 39B at the Kennedy Space Center, Florida. The vehicle was manned by Captain Alan L. Bean, Commander; Owen K. Garriott, Scientist Pilot; and Major Jack R. Lousma, Pilot.

The space vehicle, consisting of a modified Apollo command and service module payload on a Saturn IB launch vehicle, was inserted into a 231.3 by 154.7 kilometer orbit. Rendezvous maneuvers were performed during the first five orbits as planned. During the rendezvous, the command and service module reaction control system forward firing engine (quad B) oxidizer valve leaked. The quad was isolated. Stationkeeping with the Saturn Workshop began approximately 8 hours after lift-off with docking being performed about 30 minutes later.

The crewmen experienced motion sickness during the first three visit days. Consequently, the Saturn Workshop activation and experiment implementation activities were curtailed. By adjusting the crew's diet and maintaining a low work load, the crew was able to complete the adjustment to space flight in 5 days, after which the flight activities were returned to normal.

On the sixth day, the service module reaction control system quad D engines were inhibited and the isolation valves closed because of another leak. Acceptable control modes and deorbit and entry procedures were defined consistent with the constraints imposed by the two reaction control system problems.

The first extravehicular activity was delayed to visit day 10 because of the crew's motion sickness. The extravehicular activity lasted almost 6.5 hours during which time the crew changed the Apollo Telescope Mount film, deployed the twin-pole sun shield, inspected and performed repair work on the S055 (Ultraviolet Spectrometer) experiment, deployed the S149 (Particle Collection) experiment, and installed the calibration shield from experiment S230 (Magnetospheric Particle Composition).

A second extravehicular activity was performed on visit day 28 and lasted 4 hours and 30 minutes. The tasks accomplished included the installation of a rate gyro package, the deployment of a thermal shield material sample, the retrieval and replacement of the Apollo Telescope Mount work station film, the temporary stowage of the experiment S149 (Particle Collection) in the fixed airlock shroud and redeployment at the sun end, and the removal of the aperture door/ramp latch from two Apollo Telescope Mount experiments.

A third extravehicular activity was accomplished on visit day 57 with a duration of 2 hours and 45 minutes to retrieve the expended film on the Apollo Telescope Mount solar experiments and experiments S230 and S149.

Earth Resources Experiment Package activities included 39 passes with a total of 930 minutes of data. All experiment coverage was normal with the exception of the loss of experiment S193 (Microwave Radiometer/Scatterometer and Altimeter) when the antenna failed to operate during data pass 29.

A series of medical experiments was accomplished which assessed the effect of a 59-day duration space mission on the crewmen. Included were a hematology and immunology program, a mineral balance assessment, an evaluation of the changes in hormonal and associated fluid and electrolyte parameters, the extent of bone mineral loss, the cardiovascular effects utilizing the lower body negative pressure experiment and the vectorcardiogram, and an assessment of the metabolic activity.

Four astrophysics experiments were successfully performed: experiment S019 (Ultraviolet Stellar Astronomy); experiment S063 (Ultraviolet and Visible Earth Photography); experiment S149 (Particle Collection); and experiment S230 (Magnetospheric Particle Composition). Data were obtained for studies of the habitability and crew quarters, and crew activities and maintenance. In addition, several experiment M509 (Astronaut Maneuvering Unit) sequences were performed.

On the last visit day the command module was reactivated and the crew performed the final Saturn Workshop closeout. Following undocking and separation the command module entered and landed in the Pacific Ocean approximately 300 kilometers southwest of San Diego, California. The landing was at 22:19:54 G.m.t. on visit day 60, (September 25, 1973). The recovery ship, the USS New Orleans, retrieved the command module and crew 42 minutes after landing. The total flight time was 1427 hours 9 minutes and 4 seconds.

3.0 SKYLAB PARASOL

The Skylab thermal parasol provided adequate thermal shielding for the unmanned Orbital Workshop between the first and second manned visits.

A redesigned and improved thermal parasol was launched with the second visit spacecraft. However, it was not deployed as the deployment would require that the existing parasol, deployed during the first visit (ref. 3), be jettisoned. The possibility of reverting to the same thermal posture as prior to the deployment of the first parasol was too great had problems developed during the deployment of the second parasol. Therefore the twin boom sunshade, developed by Marshall Space Flight Center was deployed (fig. 3-1) over the parasol during the first extravehicular activity of the second visit.

At the time of first visit report (ref. 3) publication, the testing of the thermal parasol material had not been completed. Also, early in the second visit, samples of the parasol canopy material were exposed to sunlight. Part of these samples were retrieved on a later extravehicular activity and returned for examination to provide a basis for judging the validity of the ground simulations of sunlight that were being used to access the degradation of the canopy material. The remaining samples will be retrieved and returned after the third visit to provide a final confirmation of the long-term exposure simulations.

The degradation trends established during the first visit continued through the simulation to the end of third visit equivalent exposure. The leveling off at about 50-percent loss of strength and elongation remained unchanged throughout the remainder of the testing.

Examination of the material samples returned at the end of the second visit indicate that the simulation methods used were valid and produced acceptable results. The final conclusive validation of the simulation methods will be withheld until the remaining samples are returned and evaluated following the third visit.

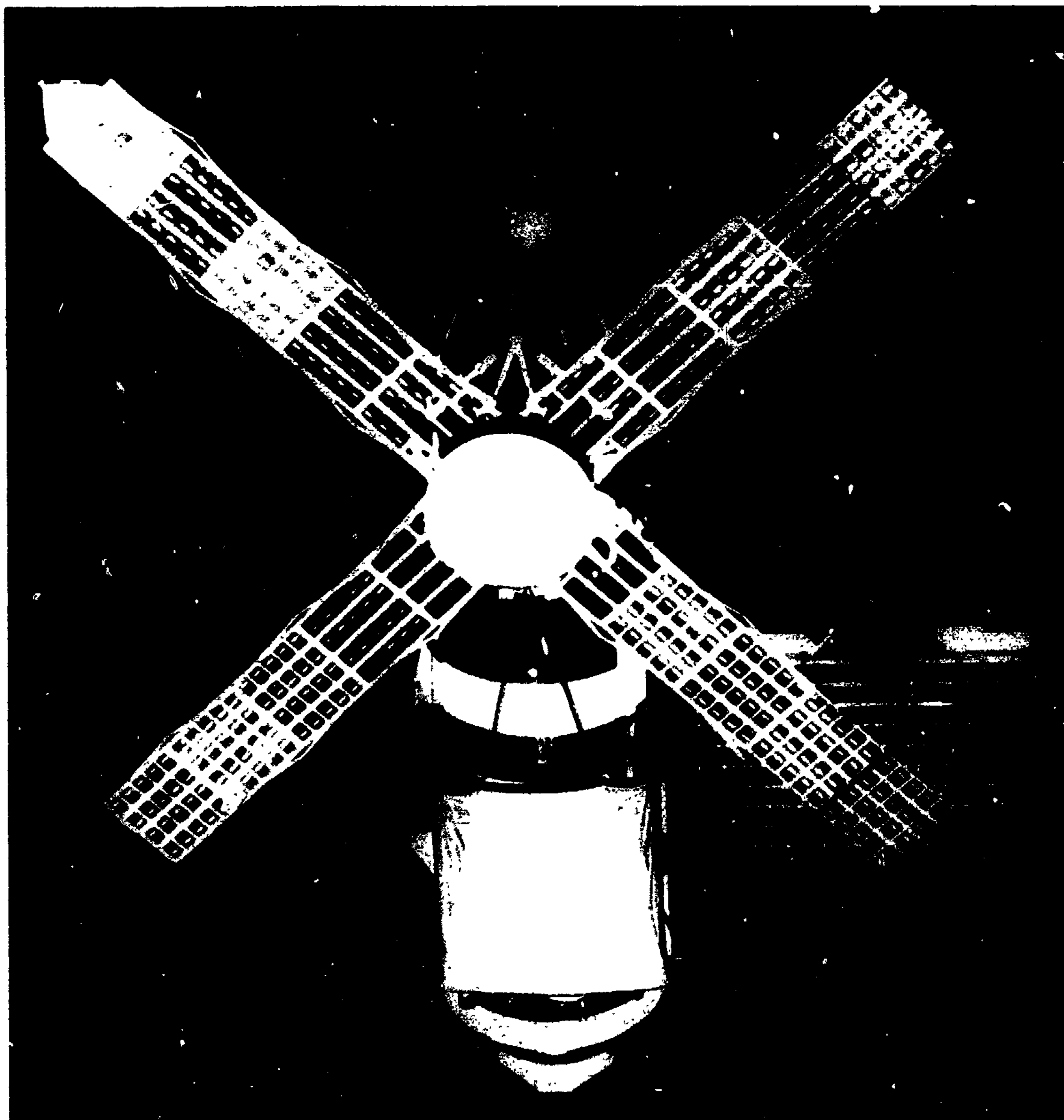


Figure 3-1.- Artist's concept of deployed twin-boom sun shade.

4.0 SCIENCE

4.1 SOLAR PHYSICS AND ASTROPHYSICS

Four solar physics and astrophysics experiments were performed. Experiment S019 (Ultraviolet Stellar Astronomy) and experiment S063 (Ultraviolet and Visible Earth Photography) were performed using the anti-solar scientific airlock. Experiment S149 (Particle Collection) was exposed between visits in the anti-solar scientific airlock. Solar exposure of experiment S149 was achieved by extravehicular deployment during the visit. Experiment S230 (Magnetospheric Particle Composition) is a passive experiment that required extravehicular retrieval of collector foils during the visit.

4.1.1 Experiment S019 - Ultraviolet Stellar Astronomy

Two film canisters were used during this visit and 272 exposures were taken. Thirty frames of data could not be exposed when the film advance lever became inoperative on one canister. A postflight examination of the malfunctioned canister showed that one of the internal limiting screws had loosened and caused the mechanism to jam. (See section 17.2.6 for additional details.)

On visit day 24, a problem occurred within the articulated mirror system of the experiment. The system failed to retract after the second use on that day. It was retracted on the following day. Details of this anomaly are contained in section 17.2.4.

Deterioration and debonding of the numerals on the articulated mirror system tilt indicator occurred. This condition was predicted prior to the launch of the Orbital Workshop but insufficient time remained to make a permanent repair. Guards were installed to seal the numerals within the counter assembly and prevent contamination of the experiment or vehicle.

A preliminary inspection of data on the film shows that hundreds of stellar spectra have been recorded, many with detailed emission and/or absorption lines. Exposures taken without using the prism on several nearby galaxies show positive results and are of good quality.

Radiation fogging was observed on most of the photographs, but it did not degrade the quality of the spectra for accurate spectrophotometry. The radiation fogging was apparently caused by the sensitivity of the ultraviolet film to temperature and radiation. This film is contained within the film vault except during operational use to minimize the effects of radiation. Also, film calibration slides within the canisters are utilized to determine the degree of fogging for data processing.

4.1.2 Experiment S063 - Ultraviolet and Visible Earth Photography

Photographic data from experiment S063 was acquired in three modes. The experiment assembly I mode (ozone photographs) was accomplished in the normal simultaneous manner at the anti-solar scientific airlock and the wardroom window. The experiment assembly II mode (twilight airglow horizon) was accomplished using the experiment S063 articulated mirror system adapter and the articulated mirror system at the anti-solar scientific airlock. The third mode consisted of hand-held photography of targets of opportunity with the 35-mm camera at the Orbital Workshop windows. The objectives of the experiment were accomplished, although some minor procedural problems contributed to some loss of data. The background fog, mostly from particle radiation, of all the black-and-white film averaged 1.06 density with the maximum exposure density of about 2.3. The resultant low contrast and density range reduced the data content of the exposures. However, color photography was very good and should yield excellent results when the analysis is complete.

4.1.3 Experiment S149 - Particle Collection

Experiment S149 was deployed on the experiment T027 extension boom from the anti-solar scientific airlock at the end of the first visit and remained deployed until shortly before docking on the second visit. The cassettes were closed by ground command after a total exposure time of 34 days and 9 hours. On visit day 4, the motor drive/cassette support unit was retracted and the cassettes were removed. Operation of the experiment during the anti-solar exposure was normal. Deployment of another set of cassettes during an extravehicular activity was required because the solar scientific airlock was still being used by the parasol. The cassettes were attached to the motor drive/cassette support unit and deployed during the first extravehicular activity. The motor drive/cassette support unit was retrieved on the third extravehicular activity after a solar exposure time of 46 days and 11 hours. The sampling surfaces were free of contamination, and a preliminary analysis of the surfaces shows craters resulting from the impact of micrometeorites.

4.1.4 Experiment S230 - Magnetospheric Particle Composition

The experiment was launched stowed under a handrail in the exterior of the Airlock Module. Photographs taken of the experiment by the first visit crew showed discoloration of the two outer (exposed) foils (fig. 4-1). This discoloration was not expected and the contamination source is unknown. As a result of the discoloration, calibration shields were installed on this visit over one of the two inner foils. These shields

Figure 4-1.- Experiment S230 in deployed configuration.

will provide a protective area on the foil that can be used for calibration and multiple exposures on the same foil. (The shields will be removed on the first extravehicular activity on the next visit.)

The contaminated (discolored) foils were removed on the first extravehicular of this visit and the calibration shields placed on one of the inner foils. The inner foil without the shields was retrieved on the last extravehicular activity of the mission.

The foil collectors were received in excellent condition. The foils were removed from their backing and they have been returned to the principal investigator in Switzerland for detailed analysis. The analysis of the contaminated foils will be greatly complicated. Partial flux data may not be retrievable but isotopic composition data may still be useful.

4.2 MEDICAL EXPERIMENTS

The planned series of medical experiments for the second Skylab visit was accomplished and, in addition, some special tests were performed. A more realistic comparison to crew baselines resulted on this visit because the internal Orbital Workshop temperatuures were normal. The medical experiment hardware performed satisfactorily with only minor intermittent problems. The glossary in appendix D contains the definitions of many of the terms used in this section.

4.2.1 Experiment M071 - Mineral Balance

Rigid control of protein, calcium, sodium, potassium, phosphorus and magnesium intake was necessary to accomplish the objectives of experiment M071. Dietary control planned around crew preferences began 21 days prior to launch and extended through 18 days after landing. The chemical composition of the potable water was also carefully controlled and the volume of the water intake was recorded. Feces and urine were collected during the control period for complete evaluation. Blood was also collected for analyses. Daily caloric intake for the inflight period was originally planned to be 250 to 300 kilocalories below that consumed during the 21-day preflight stabilization period. This planning was based on Apollo experience. After an evaluation of the first visit crew comments and data, the crew was allowed to eat more than the planned inflight caloric levels. The data from the first two visits show that nutritional requirements in zero g and one g are basically the same. Analyses of the early inflight and late inflight urine samples show a 79 percent increase in urinary calcium excretion. Urinary nitrogen losses were comparable to those of bed rest studies with a transient increase followed by a return toward the baseline.

Stereophotogrammetry was undertaken in conjunction with this experiment to document changes in body volume. A comparison of the stereophotographs taken on the day after landing and the preflight photographs revealed a disproportionate loss of body volume below the waist. This represents muscle mass as well as fluid loss.

4.2.2 Experiment M073 - Bioassay of Body Fluids

Blood and urine samples collected before, during, and after the visit were analyzed to evaluate endocrine functions for the second visit. This report reflects a preliminary evaluation of the early and late inflight urine analyses and incomplete evaluations of the preflight and postflight blood and urine results. Trends based upon these analyses revealed that:

a. The urinary sodium was increased by a moderate to marked amount during the initial inflight period.

b. The serum sodium was not changed.

c. The Scientist Pilot sustained a significant loss of extracellular fluid.

d. The urinary potassium was slightly increased.

e. The serum potassium was not changed.

f. Total exchangeable potassium was slightly decreased in two of the crewmen.

g. There was no suppression of blood levels of aldosterone inflight, contrary to that observed in bed rest studies.

h. The postflight serum cortisone values were decreased relative to previous space flight experience.

i. Epinephrine levels in the urine were elevated early in the flight and postflight periods.

j. Norepinephrine levels were somewhat higher early in the visit and during the postflight period in two of the crewmen and throughout the visit as well as in the early postflight period in the third crewman.

4.2.3 Experiment M074/M172 - Specimen and Body Mass Measurement

Two experiment M074 (Specimen Mass Measurement) devices were used to measure masses of fecal and food residues. The electronics module which failed on the waste management compartment mass measurement device during the first visit was replaced by this crew.

The experiment M172 (Body Mass Measurement) device was used satisfactorily by the three crewmen. Calibration problems associated with unstable calibration masses on the first visit were rectified by using the new mass restraints. The body mass measurement device was calibrated kthree times during the second visit.

4.2.4 Experiment M078 - Bone Mineral Densitometry

Postflight bone mineral measurements of the right distal radius and ulna (bones of forearm at wrist), when compared to preflight values obtained from the three crewmen, showed no significant mineral losses. The only significant mineral loss occurred in the left central os calcis (the heel bone) of the Scientist Pilot, but this appeared to be within the predicted limits previously determined by bed rest studies.

4.2.5 Experiment M092 - Lower Body Negative Pressure

Experiment M092 was performed on the Commander and Pilot 16 times each and on the Scientist Pilot 17 times. During the first 20 days, the intervals between tests were generally longer, as much as 5 days, with four tests on each crewman being achieved during that period. Thereafter, the tests were conducted on each crewman every 2 to 4 days.

The first inflight tests on the Scientist Pilot on visit day 5 and on the Commander on visit day 6 were terminated early because of presyncopal symptoms. During the fourth test on visit day 20 and the twelfth test on visit day 46, the Commander developed presyncopal symptoms late in the final phase and, therefore, the tests were terminated early. The resting and stressed heart rates of the crewmen remained slightly to moderately elevated above their preflight ranges throughout the flight. A trend toward normal ranges appeared to be developing during the last three weeks of the visit.

The resting calf circumference in the crewmen declined rapidly during the early part of the visit in a pattern much resembling that seen in the first visit crewmen. Calf circumference loss continued but at a decreased rate during the remainder of the visit. The increase in leg

volume during the performance of lower body negative pressure tests was greater during the flight than during the preflight period. The magnitude of difference between inflight and preflight values did not reach that seen in the first visit crewmen.

Cardiovascular responses to the lower body negative pressure on the first postflight examination resembled those seen after the first visit. The second visit crew appeared to reach their preflight status somewhat earlier than the first visit crewmen with heart rate responses in the crewmen falling within the preflight range in the tests 5 days after landing.

With the exception of the failure of one leg band to calibrate properly (see section 17.2.2) the hardware performed satisfactorily.

Special lower body negative pressure tests were conducted primarily to measure lower limb blood-flow during exposure to negative differential pressures. The purpose of these tests was to better understand the hemodynamics related to the exaggerated leg volume changes observed during the inflight phase of experiment M092. The tests were performed once on the Scientist Pilot and twice on the Commander and Pilot.

4.2.6 Experiment M093 - Vectorcardiogram

Experiment M093 was performed 16 times each by the Pilot and Commander and 17 times by the Scientist Pilot.

Resting heart rates were slightly elevated and an increase in P-R interval, which was not clinically significant, was seen in the crewmen. Other observed changes in waveform duration, azimuth, and magnitude were inconsistent and also without clinical significance.

By 9 days after landing, the magnitude of the QRS vector of the crewmen remained slightly elevated, but all other observed inflight changes had returned to preflight values.

4.2.7 Experiment M110 Series - Inflight Blood Collection

The blood withdrawal and plasma separation system was used eight times on each crewman. Beginning with the third weekly blood withdrawal, six blood hemoglobin determinations were performed. Six urine specific gravity determinations using the refractometer were also performed on as many samples from each crewman. In addition to the blood returned in the automatic sampling processors, three blood sampling vials per crewman were used to fix red cells for return and analysis. One of these small vials had leaked fixative solution and a spare vial was used.

The eight venipunctures per crewman were accomplished without difficulty, yielding 88 milliliters of blood per crewman as planned. Preliminary data from the early postflight samples are summarized in the following paragraphs.

4.2.7.1 Experiment M111 - Cytogenetic Studies of the Blood.- This experiment was conducted to determine the genetic consequences of long duration space flight. The preflight and postflight cultures were satisfactorily prepared and the specimens were adequate for the proposed evaluation. Analysis of this material has not been completed.

4.2.7.2 Experiment M112 - Hematology and Immunology.- This experiment was conducted to assess the changes in humoral immunology. Plasma proteins and immunoglobins showed no change from preflight levels. Serum complement factor C_3 and lysozyme likewise did not show changes in the postflight samples. In vitro antigenic stimulus showed significant depression of ribonucleic acid (RNA) and deoxyribonucleic acid (DNA) synthesis rates in the samples taken on the day of landing, but on the third day after landing, the rates had returned to normal.

4.2.7.3 Experiment M113 - Blood Volume and Red Cell Life Span.- This experiment was conducted to determine effects of weightlessness on plasma volume and red blood cell populations. The average reduction in red cell mass of 12.3 percent was comparable to the first visit findings. However, by 14 days after landing, most of this loss had been restored. This restoration rate is considerably faster than that observed in the first visit crew. Plasma volumes were reduced by approximately 10 percent in the three crewmen. From body weight data and other hematologic data, a significant amount of this loss had apparently been regained by the 14th day after landing.

4.2.7.4 Experiment M114 - Red Blood Cell Metabolism.- This experiment was conducted to determine metabolic and/or membrane changes occurring in the red blood cells. In the postflight samples, a decrease in intracellular reduced-glutathione has been observed. The significance of this finding is under study.

4.2.7.5 Experiment M115 - Special Hematologic Effects.- The red blood cell count, hemoglobin and hematocrit values were found to be significantly reduced during the postflight period, reflecting the changes observed in red cell mass and plasma volume. The specific gravity of the red cells shifted slightly toward heavier (older) cells in the landing day determinations, but was essentially normal on the day after landing. This is believed to represent a fluid shift consistent with a plasma volume change. Red blood cell osmotic fragility was not significantly different from preflight values.

White blood cell counts as well as differential counts showed a normal reaction to the stress of deorbit and entry with an increase in neutrophils. Beginning with the third inflight blood collection, hemoglobin and urine specific gravity determinations were made by the Scientist Pilot using equipment from the inflight medical support system. The elevated hemoglobin and urine specific gravity values found at the time of this and subsequent blood draws tend to support the assumption that the plasma volume loss occurs early in the visit and persists.

4.2.8 Experiment M131 - Human Vestibular Function

Motion sensitivity and oculogyral illusion testing were accomplished three times on the Commander and six times each on the Scientist Pilot and Pilot. Spatial localization testing was also performed three times on each of the three crewmen. The hardware operated satisfactorily.

4.2.8.1 Inflight.- Upon initial entry into weightlessness, the three crewmen experienced motion sickness symptoms, the most severe in the Pilot. Complete remission of these symptoms occurred after approximately visit day five. From that point on, the crewmen were dramatically refractory to motion sickness symptoms as provoked by the experiment protocol.

By the midpoint in the visit, both the Scientist Pilot and Pilot were able to perform the maximum required number (150) of head movements at the maximum rotating chair speed (30 revolutions per minute) with no symptoms of illness. These crewmen continued to perform at the maximum motion sensitivity protocol for the remainder of the visit with no significant difficulties. Although he had not originally been scheduled for the motion sensitivity test, the Commander began to participate as a subject midway through the visit, and like the other crewmen, quickly advanced to the maximum motion sensitivity protocol level.

The six oculogyral illusion tests performed by the Scientist Pilot and the Pilot demonstrated a slight increase in their ability to perceive the illusion when compared to preflight tests. The three tests the Commander performed showed essentially no change from the preflight baseline.

Three spatial localization tests were conducted by each crewman. A preliminary analysis of these data indicates slight shifts in localization and slight increases in variability relative to preflight measurements.

4.2.8.2 Postflight.- The three crewmen were far less susceptible to motion sickness on the first two days after landing and five days after landing, as compared with their preflight baseline tests. A further test performed on the Scientist Pilot and Pilot 17 days after landing indicated that these crewmen had returned to the upper range of their preflight susceptibility. The Commander was not tested on the 17th day. A minimum

of one additional motion sensitivity test on each of the crewmen will be required to determine the time course and completeness of their return to baseline levels. No significant changes relative to preflight baselines were noted with either the oculogyral illusion or the spatial localization test in any of the crewmen.

4.2.9 Experiment M133 - Sleep Monitoring

Twenty of a scheduled twenty-one sleep monitoring runs were accomplished on the Scientist Pilot. Problems occurred on one run when the sleep cap electrodes were lacking a sufficient quantity of electrolyte to conduct the output signal.

The early thermal problems of the Orbital Workshop dried out electrolite fluid in the cap electrodes. For this reason, the Scientist Pilot used an electrolyte resupply kit to rejuvenate the cap electrodes prior to each usage.

Initial observations show the data to be of high quality and a preliminary evaluation indicates the following:

a. The time required to get to sleep (sleep latency) averaged 0.2 hour preflight and 0.29 hour inflight.

b. The absolute total time in bed (rest time) both preflight and inflight was the same, 7.5 hours. The total sleep time averaged 6.4 hours preflight and 6.7 hours inflight.

c. A summary of sleep-stage characteristics (table 4-I) shows that sleep latency increased slightly inflight, but total sleep rose a small amount. The inflight tendency was toward a lighter sleep in that stages 3 and 4 showed a small decrease while stage 1 increased. Stage REM shows a slight change, averaging 14.7 percent before and 16 percent during the flight. None of the observed changes should alter the performance capability.

4.2.10 Experiment M151 - Time and Motion Study

Photographic coverage of 29 activities was accomplished during this visit and these data are being analyzed.

TABLE 4-I.- SLEEP STAGE CHARACTERISTICS

Stage	Prominent features
W (Wakefulness)	Electroencephalogram contains alpha activity (8 to 12 hertz) and/or low voltage, and mixed frequency activity. Relatively high tonic electromyogram and eye blinks are often present in the electrooculogram.
1	Transition stage from wakefulness to sleep. Low voltage, mixed frequency electroencephalogram activity without rapid eye movements. Prominence of activity in the 2 to 7 hertz range with presence of slow eye movements.
2	Presence of sleep spindles (12 to 14 hertz) and K complexes (wave form with negative sharp wave immediately followed by positive component) on a background of low voltage, and mixed frequency activity.
3	Moderate amounts of high amplitude, slow wave (2 hertz or slower) electroencephalogram activity.
4	Large amounts of high amplitude, slow wave electroencephalogram activity.
REM (Rapid eye movement)	Low voltage, mixed frequency electroencephalogram in conjunction with episodic rapid eye movements and low amplitude electromyogram. Sleep stage associated with dreaming.

4.2.11 Experiment M171 - Metabolic Activity

The experiment support hardware functioned satisfactorily and all objectives were accomplished. Nine runs each were accomplished on the Commander and the Pilot and ten runs were accomplished on the Scientist Pilot. The ergometer was utilized approximately 20 minutes per day per crewman as an exercise device. During an exercise period on visit day 20, the ergometer load module began making excessive noise and eventually began to freewheel (no load). (See section 17.2.7 for a discussion of this anomaly.) After a one-hour cooldown period, the ergometer functioned properly and continued to operate satisfactorily for the remainder of the visit. The addition of an adjustable bar restraint for encircling the ergometer rectified the restraint problem reported on the first visit.

The crew's inflight physiological response to mechanical work approached preflight baseline ranges after their initial exposures and remained within these ranges throughout the remainder of the visit. Immediately postflight, all crewmembers exhibited a significant decrease in their response to the experiment protocol as compared to preflight or inflight responses. The most obvious indications of this were elevated heart rates, increased oxygen consumption, and decreased cardiac output for the same work load. These changes were of the same order of magnitude as observed on the first visit crew, but returned to normal more rapidly. Preflight baseline range values were reached 5 days after landing.

4.2.12 Experiment S015 - Zero Gravity Effects on Human Cells

The experiment S015 hardware operated normally and the initial cell photographic data analysis indicate excellent results. The experiment package was originally designed for operation during the 28-day duration of the first visit and was to be installed in the command module. However, the experiment was removed from the command module to make room for other required equipment to resolve the thermal problem that existed in the Orbital Workshop prior to the first visit. As a result, the experiment hardware was redesigned to operate on the 59-day duration second visit. The experiment hardware was returned to the principal investigator for cell analysis 1 day after the landing of the second visit spacecraft.

4.2.13 Experiment S071/S072 - Circadian Rhythm of Pocket Mice and Vinegar Gnats

Two experiment assemblies were activated and loaded with live specimens 6 days prior to launch. One experiment assembly was installed in the command and service module 3 days prior to launch. The other experiment assembly was operated in a laboratory at the Kennedy Space Center for 29 days to provide comparative data for the flight assembly.

Experiment measurements were functioning and the system parameters were normal prior to a failure at about 34 hours after launch when all data were lost. (A detailed discussion of this anomaly is presented in section 17.2.1.) None of the scientific objectives were accomplished.

4.2.14 Visual Light Flash Phenomena

The first and second visit crewmembers experienced visual light flashes as reported on previous flights. Only casual observations were made by the crew during their pre-sleep period and these were of about the same frequency and character as previous observations.

The current hypothesis is that the flashes are caused by heavy cosmic particles. Most of the flashes are believed to be caused by particles interacting directly with the retinal rod cells, although Cerenkov radiation may also be a contributing factor.

Heavy cosmic particle effects are not believed to be of any significant biological concern for these relatively short flights. Even for longer duration flights the particles may prove of little consequence because of their relatively low intensity. However, the mechanism responsible for this phenomenon is still unknown. A light flash test is planned for the third visit.

4.3 EARTH OBSERVATIONS

This section describes the performance of the Earth Resources Experiment Package during the second visit. Specific sensor evaluation performance is contained in reference 4. Thirty-nine Earth Resources Experiment Package data passes were performed with the spacecraft in the Z-axis local vertical attitude and five passes were performed in the solar inertial attitude. The Earth Resources Experiment Package diagnostic downlink unit was used on 14 occasions to provide data for real-time analysis and troubleshooting.

4.3.1 Experiment S190A - Multispectral Photographic Facility

The Multispectral Photographic Facility performance was satisfactory. Approximately 1850 frames were exposed at each of the six camera stations.

The overall sharpness and resolution of the photography was good. The reseau lines are clearer and there is less evidence of emulsion or base scratches than found on the first visit film. In addition, less reseau plate contamination was noted. In isolated instances, a particle would float under the reseau plate, causing a small diffuse shadow on the film image.

Like the first visit, some interlens contamination of particulate material was observed and some film scratches were found on the final three film loads. Some electrostatic discharge markings similar to those of the first visit occurred on some black-and-white infrared film.

Five percent of the photography was lost during the fifth Earth Resources Experiment Package pass because of procedural errors.

On the final two film loads at station 6, during two Earth Resources Experiment Package passes, a single spurious frame advance occurred between commanded exposures, but this caused no loss of photography. See section 17.2.8 for details on this anomaly.

Some frames exposed at the fast shutter speed exhibit a lack of proper contact between the film and the reseau plate at the format corners. Either a tardiness of pressure platen operation or a loss of resiliency of the elastomer foam platen pad would cause this lack of contact.

4.3.2 Experiment S190B - Earth Terrain Camera

The experiment was used during 33 Earth Resources Experiment Package passes, 6 special passes, and 1 lunar calibration pass. Because of the camera's high resolution capability and ease of operation, the camera was used for real-time photographic tasks beyond the planned Earth Resources Experiment Package coverage.

With one exception, camera performance was good. At the end of the second pass, the camera system was automatically shut down by the thermal switch in the shutter drive after exceeding the 30-minute continuous operation limit. Procedures were modified on subsequent passes to prevent reaching the time limit.

On visit day 47, the camera's clock lock knob came loose and was lost. These parts will be made available for the third visit.

4.3.3 Experiment S191 - Infrared Spectrometer

Experiment S191 performed satisfactorily. The data reviewed were within expected limits and in good agreement with the data from the first visit. The acquisition and tracking of targets with the viewfinder tracking system was accomplished.

On visit day 12, the operation of the aperture door was reported as erratic with the closure time approximately 50 percent greater than normal. During postflight debriefings, the crew further defined the door operation as continuous motion with the speed of operation varying. (Section 17.2.3 contains details of this anomaly.) To preclude a failure of the door mechanism, the door was left open on the ninth Earth Resources Experiment Package pass and was not closed until after the final pass. No discernible degradation in spectrometer performance resulted from leaving the door open for the 40-day period.

Pictures obtained with the data acquisition camera using color film were an improvement over those taken with the black-and-white film during the first visit. Data acquisition camera performance was good, but two procedural problems occurred. The camera was mounted improperly (rotated 90 degrees) during four passes. On two occasions, improper alignment of the film perforations with the indexing stripes on the magazines caused improper framing. Approximately 40 pictures were affected. A shortage of the prescribed film occurred because 13 additional passes were conducted. The final passes used film that had a slower exposure rating and, as a result, some of those frames were under exposed.

The television camera was operated on passes 14 and 21 with the viewfinder tracking system and operation was normal.

4.3.4 Experiment S192 - Multispectral Scanner

The experiment performed satisfactorily. The quality of the data was improved by two actions taken by the crew to correct conditions which existed during the first visit. First, the cooler-detector was seated correctly in its mount and, second, the attenuator was readjusted.

The data show that the high readings experienced on monitors A2 (band 1-automatic offset control) and C4 (band 11-automatic gain control) during four consecutive Earth Resources Experiment Package passes were caused by the alignment light-emitting diodes being inadvertently left on. Imagery data from these passes exhibited dark and light stripes at a frequency of 1.5 kilohertz. The intensity of the stripes varied from band to band with increasing intensity toward bands 1 and 11. Ground testing has confirmed that the light-emitting diodes will cause this effect if turned on during a data taking period. The same problem also occurred during one pass on the first visit.

The banding (low-frequency noise) was prevalent in the thermal channel imagery. Extensive analyses and ground tests have shown that the low frequency noise that results in this banding is caused by the 1/f noise (amplitude inversely proportional to frequency) of the detector, which is a fundamental limitation of solid state devices. Limited preflight testing of the thermal channel, necessitated by schedule constraints, prevented detection of this problem prior to launch. New thermal detectors with better 1/f noise characteristics are being considered for the next visit. Data processing techniques have been developed to reduce the effects of banding.

A herringbone pattern was present on some of the imagery, and was caused by a 20-kilohertz noise induced into the data on the four attenuated bands during both visits. The noise can be reduced by modifying the grounding in the attenuator. A new attenuator with better grounding is planned for the next visit. The herringbone noise can be removed with data reduction techniques.

4.3.5 Experiment S193 - Radiometer/Scatterometer/Altimeter

Performance through pass 28 was satisfactory and was quite like that of the first visit: two altimeter mode 3 data frames were still missing, altimeter mode 5 compression network remained inoperative, and the antenna continued to exhibit an inability to reach the maximum scan angles. The radiometer automatic gain control saturation during altimeter operation was avoided by a procedural change. Saturation of the radiometer automatic gain control occurred once during scatterometer only operation.

The altimeter nadir alignment functioned within its ±9 milliradian accuracy and the return pulse shapes were noticeably better immediately after an alignment. However, like the first visit, vehicle attitude errors resulted in distorted pulse shapes.

During the 29th pass, a receiver malfunction light came on and the equipment failed to function properly for the rest of the visit. Analysis showed that antenna control was lost. Consequently, no usable science data were obtained from this experiment occurrence of this failure. This anomaly is discussed further in section 17.2.5.

4.3.6 Experiment S194 - L-Band Radiometer

The L-band radiometer, which is passive, continued to perform satisfactorily. The electronics enclosure temperature was several degrees colder than the design level, similar to the first visit. Tests have established that adjustments for low temperatures will be required in processing the data.

4.3.7 Tape Recorder

The primary tape recorder was used to record the first 36 passes of Earth Resources Experiment Package data and the recorder performance was normal. The secondary tape recorder was used for the last three passes and the performance was similar to the first manned visit in that the data recorded on tracks 3 and 13 were of marginal quality. (A low signal-to-noise ratio existed causing data dropouts.) Data on tracks 3 and 13 were marginal during all three passes and data on track 17 was marginal for three 1-minute intervals. In any event, the data are recorded redundantly on other tracks. Consequently, no data were lost.

During the last Earth Resources Experiment Package pass, the secondary recorder tape motion light flickered on three separate occasions during the 1.524 meters-per-second recording mode. This condition was also noted during the first visit and is discussed in section 17.2.4 of the first visit report. Recording heads characteristically incur a buildup of debris followed by an instantaneous self-cleaning action. Consequently, this type of problem with the recording track is not abnormal. The heads are cleaned after the completion of each Earth Resources Experiment Package pass and the tape path is cleaned after removing each reel.

Returned tapes were examined visually. The tapes do not appear to be as tacky as those from the first visit; however, six of the thirteen tapes from this visit occasionally had a dark, sticky material dispersed across them.

5.0 ENGINEERING AND TECHNOLOGY EXPERIMENTS

5.1 ENGINEERING

The engineering experiments performed were the M487 (Habitability and Crew Quarters), M509 (Astronaut Maneuvering Equipment), and M516 (Crew Activities/Maintenance). Only experiment M509 required use of special hardware. The technology experiment T053 (Earth Laser Beacon), was approved and scheduled during the mission and required no flight hardware.

5.1.1 Experiment M487 - Habitability and Crew Quarters

Objectives of the experiment were accomplished and, in some instances, additional data were received. The visceral awareness experienced by this second visit crew hampered the total environmental adaptation and the establishment of routines to handle the daily nonexperimental functions. Numerous common reactions were noted by both the first and second visit crews concerning various aspects of habitability such as: low illumination levels, messy food operations, ease of mobility, pleasing performance of hygiene equipment, and the necessity for concurrent sleep periods. However, there were marked differences of opinion between the two crews concerning certain aspects of habitability:

a. The Apollo Telescope Mount chair was not used.

b. The shower use was very limited; however, sponge baths were used.

c. The firemen's pole was removed as unnecessary.

d. Different ensemble combinations of clothing were adapted by each crew as the standard uniform-of-the-day.

e. The first crew changed footware daily as the chores dictated, whereas this crew wore triangle shoes almost exclusively.

Some indications of personal preference are indicated, but the differences exhibited require further analysis to insure that improper design did not contribute to the lack of desirability of use.

The environmental instruments were used more by this second crew and certain instruments were used to troubleshoot equipment operations, such as the digital thermometer to measure the gyro six-pack temperatures.

One significant procedural change effected by this crew with regard to the experiment M487 subjective questionnaire debriefings will be implemented on the next visit. Previously, the entire crew had been scheduled to participate in the debriefing, but these crewmen chose to answer questions individually, and the data returned was such that the practice will be continued.

5.1.2 Experiment M509 - Astronaut Maneuvering Equipment

Six runs were completed with a total flying time of 8 hours, although only four runs were scheduled. On one of the two additional runs, the Commander performed some exploratory maneuvers for which he trained. On the other run, the Scientist Pilot, who had no prior training, demonstrated the ease with which a person familiar with spacecraft maneuvering techniques can adapt to flying the automatically stabilized maneuvering unit. Some data were lost because of telemetry dropouts and Airlock Module tape recorder malfunctions.

The functional objectives were completed except the suited run. The stiffness and inertia of the suit's life support umbilical caused the propellant consumption rate to be high and also affected maneuvering precision.. Because of the umbilical, several maneuvers were not performed. On the next visit, a life support umbilical consisting of only the oxygen hose will be used. Thirteen minutes of flying time using the secondary oxygen package (no umbilical) was made and useful data were recorded. Another difficulty during the suited run was that yaw rotation commands in the control moment gyro and rate gyro modes were tiring to maintain because of the difficulty in gripping the hand controller tightly enough with the pressurized glove to avoid slippage. Also, all data were slightly degraded because the center of gravity was displaced from the thrusters when position was cramped by a backspacer, intended for shirtsleeve runs only, that was left in place. During the first experiment run, the restraint harness did not hold the Commander securely during rolling maneuvers. Supplemental restraints, consisting of two equipment tethers, corrected the situation.

In general, the automatically stabilized maneuvering unit modes were operated with great precision. Specific tasks included inspection, cargo transfer, rescue, retrieval, tracking, tumble recovery, rendezvous stationkeeping, and docking. The Commander also flew with the hand-held maneuvering unit, but with less precision. Portions of the first and fifth runs were flown by the Pilot. Although not a part of the requirements, the data will be useful.

The voltmeter and battery tester launched on this visit were used to verify that the battery cells and total voltage levels were within limits prior to use. The maneuvering unit was not operated on internal power

during the first visit because of the uncertain condition of the nickel-cadmium batteries after the high temperatures experienced during the first 10 days after the Orbital Workshop was launched. The battery tests, developed for this flight, showed that the cell balance was good.

The control moment gyro yaw wheel B, which was slow in spinning up on the first visit, gradually improved on this second visit and finally operating normally.

5.1.3 Experiment M516 - Crew Activities/Maintenance

Excellent data were obtained and five of the seven objectives of the experiment were accomplished. The quality of the data was enhanced significantly by photographing the troubleshooting and repair activities. Additional data were obtained with a 122-meter cassette of 16-mm film from the first visit on which maintenance activities were photographed late in the mission.

5.2 TECHNOLOGY

5.2.1 Experiment T053 - Earth Laser Beacon

A series of tests were conducted on this visit using the earth laser beacon station located at the Goddard Optical Research Facility, Greenbelt, Maryland. The tests were to gather baseline data on laser visibility and ground station operational performance. The earth laser beacon station met the operational requirements. The first visual sighting of the beacon by the crew was on visit day 54. The laser beacon was visible for 5 minutes during which the Orbital Workshop reached a maximum elevation angle relative to the laser station of 0.768 radian. The laser power transmitted was a continuous 10 watts at 5145 angstroms; the laser beam's full angular divergence was 0.002 radian. The visibility was excellent with clear skies and low humidity. The second visual sighting occurred on visit day 55. The laser beacon was visible for 2 minutes and the Orbital Workshop reached a maximum elevation angle relative to the station of 0.855 radian. The laser power transmitted was a continuous 2.5 watts at 5145 angstroms and the beam divergence was 0.002 radian. During this pass, the crew reported that the laser source appeared as a line of multiple beams rather than a point. The appearance of multiple beams will be investigated further on the next visit.

6.0 FOOD AND MEDICAL OPERATIONAL EQUIPMENT

6.1 FOOD

The food system launched aboard the Orbital Workshop supported the second visit crew adequately. An inventory of the remaining food was made and maintained during the visit to support plans to extend the second visit for 3 days beyond the 56 days, and also to extend the third visit.

The phenomenon of an increased taste threshold by the crew was the same as experienced on the first visit. Basically, the food had a blander taste in orbit than on the ground. Increased salt consumption was allowed to correct some of the bland taste. As a result, the crew consumed nearly all the onboard salt, and the sodium chloride tablets were also used to augment the salt supply. A special taste evaluation kit will be launched for the next visit to obtain data to better characterize the condition.

Some of the reports on the taste and appearance in the food were:

a. Strawberries - brownish in color, soft, and lacked flavor

b. Asparagus - brownish in color, with more stalk than top

c. Pork loin - unpalatable to the Scientist Pilot and therefore not eaten

d. Bread - unpalatable and the Pilot ate it only when jam was available

e. Tuna salad - umpalatable and therefore not eaten.

Ground tests are continuing on the control and flight food items. These tests have shown no harmful bacteria, toxins, or other chemical constituents. Because the flight items were subjected to high temperatures before the first visit, eight additional food items were returned by the second visit crewmen for further evaluation.

A redesigned salt and spice kit will also be launched on the next visit. The crew reported difficulties in using conventional shakers and bottle-type dispensers, and made recommendations for dispensing spices. These recommendations were incorporated into the specially designed kit.

6.2 MEDICAL OPERATIONAL EQUIPMENT

The medical operational equipment performed satisfactorily.

6.2.1 Inflight Medical Support System

Problems were encountered with usage of two items of the inflight medical support system beginning with visit day 20:

a. Inflight hemoglobinometer readings were higher than those obtained preflight. For this reason, a calibration shift of the hemoglobinometer was suspected. The device was returned and postflight analysis has indicated that the unit functions properly.

b. Urine specific gravity measurements were accomplished from visit day 30 through the end of the visit using the urine refractometer. Attempts to recalibrate this device during the flight resulted in a value nearer the desired level; however, the unit was returned for postflight analysis and calibration.

A calibrated hemoglobinometer and urine refractometer are being launched for the next visit. Syringes, ethanol, vials, and like medical items used by the crew to clean the magnetic tape recorder head, support other scientific demonstrations, and perform equipment maintenance will be resupplied.

6.2.2 Operational Bioinstrumentation System

The operational bioinstrumentation systems were used during launch, extravehicular activities, a suited experiment M509 run, and entry. Good electrocardiogram and impedance pneumograph data were obtained during these periods and no loss of data was experienced.

6.2.3 Exerciser

In response to crew comments on the first visit, an exercise device was launched with the second visit crew to provide back and leg (calf) conditioning. The device functioned normally, except for pull rope breakage. This anomaly is discussed in section 17.3.1.

7.0 COMMAND AND SERVICE MODULES

This section contains the performance evaluation of the command and service module systems.

7.1 STRUCTURES AND MECHANICAL SYSTEMS

The command and service module vehicle structure and mechanical systems performed satisfactorily.

7.2 THERMAL

The command and service module thermal control system configuration differed from the first visit spacecraft only in that the thermal tape used on the electrical power system radiators was deleted.

The second visit spacecraft temperatures followed the trends of the first visit. Temperatures were within acceptable limits. Table 7-I compares the service module reaction control system temperature limits to the flight data. The descent battery maximum temperature when switched on to the bus was several degrees cooler than the first visit because of lower Beta angles reducing the solar heating.

7.3 ELECTRICAL POWER, FUEL CELLS, BATTERIES AND CRYOGENIC STORAGE

7.3.1 Electrical Power Distribution

The power distribution system performance was satisfactory. After docking, the command and service module was powered down to the planned quiescent power level of approximately 1300 watts. Upon depletion of fuel cell reactants, the command and service module received power from the Saturn Workshop power sources. Power management was normal.

Two discrepancies occurred. The first was noted on the second visit day when the cryogenic hydrogen tanks were configured with the tank 1 fans and heater off and the tank 2 fans and heater in automatic for faster tank 2 depletion. However, pressurization cycles were noted in tank 1, and tank 1 began to deplete at a faster rate than tank 2. On visit day 11, the tanks were reconfigured with the tank 1 fans and heaters in automatic

TABLE 7-I.- SECOND VISIT REACTION CONTROL SYSTEM TEMPERATURE DATA

Category/name	Temperature, °K			
	Limit		Recorded	
	Maximum	Minimum	Maximum	Minimum
Quad A				
Engine package	394	286	355	297
Oxidizer line	352	267	317	286
Helium tank	333	267	311	292
Fuel tank	332	272	312	296
Quad B				
Engine package	394	286	Sensor failed	
Oxidizer line	352	267	298	273
Helium tank	333	267	295	279
Fuel tank	332	272	296	283
Quad C				
Engine package	394	286	338	296
Oxidizer line	352	267	299	274
Helium tank	333	267	298	278
Fuel tank	332	272	299	280
Quad D				
Engine package	394	286	338	296
Oxidizer line	352	267	298	268
Helium tank	333	267	298	286
Fuel tank	332	272	298	282

and the tank 2 fans and heaters off. Pressure cycles and faster depletion were then apparent in tank 2, leading to the conclusion that the wiring for the two tanks was interchanged. Section 17.1.3 contains a discussion of this anomaly.

At 3:20:21 G.m.t. on visit day 8, a master alarm occurred in the command and service module at approximately the same time that an electrical short circuit of about 250 amperes occurred in the Orbital Workshop. All command and service module system data were normal at the time. Circuit analysis disclosed that a short circuit current to structure, anywhere in the total space vehicle, would have to traverse structure and re-enter the ground return system wiring through the vehicle ground point in the command module. Although the resistance of the path through the command module is small, 250 amperes provides a change in voltage between the vehicle ground point and the Multiple Docking Adapter interface of about 2 volts. Since many of the command module caution and warning returns are referenced to various points along this path, a momentary voltage differential occurs on the caution and warning channels. Analysis concluded that the Orbital Workshop short caused the spurious master alarm in the command module.

7.3.2 Fuel Cells

Fuel cell performance was normal. Fuel cell 1 was on bus A and fuel cell 3 was on bus B at launch. The buses were placed in parallel on the second visit day and remained in that configuration through fuel cell shutdown, on visit day 20. Low fuel cell loading and low radiator temperatures caused the fuel cell 3 condenser exit temperature to be sufficiently low to trip the master alarm on the second visit day. The alarm was inhibited late in the second day to preclude recurrent alarms. Later, from data analysis and system observation, the radiator area control valve was changed to reduce the radiation area from eight panels to five panels. The fuel cell radiator temperature and the condenser exit temperature then stabilized within the normal operating ranges.

The fuel cells provided 20 700 ampere-hours of energy from lift-off through shutdown at an average bus voltage of 29.3 volts.

7.3.3 Cryogenic Storage

The command and service module cryogenic oxygen and hydrogen tanks were loaded 2 days before lift-off. Oxygen tank 2 was intentionally offloaded to 77 percent capacity prior to launch to preclude inflight venting.

The thermal performance of the cryogenic hydrogen and oxygen storage systems was normal and the wiring problem mentioned in section 7.3.1 had no effect on the system function.

When the fuel cells were shut down, the hydrogen vent was opened and the residual hydrogen was vented overboard. The cryogenic oxygen system was managed, after fuel cell shutdown, by flowing oxygen through the poly-choke orifice into the command module with occasional overboard venting through the command module side hatch vent. Cryogenic hydrogen and oxygen quantities are summarized in the consumables section of this report.

7.3.4 Batteries

The entry and postlanding batteries, pyrotechnic batteries, and descent batteries performed normally.

Command module entry batteries A and B were charged during the countdown and once after docking. These batteries supported the launch, all service propulsion system maneuvers, and the service propulsion system checks. Entry battery C was placed on the main buses with batteries A and B to support the total command module power requirements through entry, landing, and postlanding. Entry battery usage between undocking and landing was 62 ampere-hours. The estimated capacities remaining at landing were: battery A - 25 ampere-hours; battery B - 23 ampere-hours; and battery C - 30 ampere-hours.

The service module descent batteries supported the primary power requirements of the command module. Descent battery 1 delivered 407 ampere-hours, battery 2 delivered 52 ampere-hours, and battery 3 delivered 359 ampere-hours up to the time of command module/service module separation. Battery 2 was placed on main bus A with battery 1 approximately 4 hours prior to command module/service module separation to minimize the temperatures of batteries 1 and 3. The maximum battery 1 temperature of 340° K was well within the temperature limit. Total estimated usage was 818 ampere-hours of the rated 1500-ampere-hour total capacity. The predicted usage was 830 ampere-hours. Pyrotechnic batteries A and B performed the required pyrotechnic functions.

7.4 COMMUNICATIONS AND TELEVISION

7.4.1 Communications

The communications system satisfactorily supported the second visit. Performance of the VHF ranging system was commensurate with preflight predictions. VHF ranging system operation was limited to the phase of each orbit where the Orbital Workshop ranging antenna beam was pointed toward the command and service module because the Saturn Workshop was in a solar inertial attitude during the rendezvous.

The video tape recording of the web formation experiment contained noisy audio because of a hand-held microphone problem. This anomaly is discussed in section 17.3.6.

A problem was experienced with the up-data link. Failure of one real-time command relay to respond caused the data storage equipment to rewind when the tape stop command was sent. This anomaly is discussed in section 17.1.4.

After landing, salt water collected in the connectors on the docking tunnel, shorting out the exposed pins for the keying function of audio panels 6 and 9. This keyed the VHF transmitter continuously and prevented reception by the crew. Crew procedures for the third visit will be revised to preclude recurrence of this problem.

7.4.2 Color Television Camera

Two color television cameras were resupplied for the second visit. Each performed as expected except for the following problems;

a. The color wheel filter in the backup camera stalled when first used during the predocking inpsection. Manual rotation of the filter wheel restored normal operation.

b. The primary camera failed during the second extravehicular activity as the result of overheating.

c. Later in the visit, a video tape recorder dump contained no video. The problem was isolated to an open circuit in the camera power cable.

d. One of the two monitor cables developed an intermittent condition and had to be replaced with the spare cable.

These anomalies are discussed in sections 17.3.3, 17.3.4, and 17.3.5. A television camera will be resupplied for the third visit.

7.5 INSTRUMENTATION AND DISPLAYS

The instrumentation and displays performed satisfactorily with the exception of the following four problems.

a. The command module reaction control system helium manifold pressure indication oscillated between 57.9 newtons per square centimeter and 61.4 newtons per square centimeter on the eighth and ninth visit days. Section 17.1.9 contains a discussion of this anomaly.

b. The oxidizer interface pressure indication was reduced from 110.3 newtons per square centimeter to 93.1 newtons per square centimeter during loss of signal between 4:56 G.m.t. and 5:00 G.m.t. on the 59th visit day. Section 17.1.7 contains a discussion of the anomaly.

c. The indicated pressure for the service module reaction control system C oxidizer manifold unaccountably increased 6.2 newtons per square centimeter during the duration of the visit. The problem is characteristic of the gradual loss of the transducer reference cavity pressure.

d. The service module reaction control system quad B engine package temperature measurement was intermittent for approximately 4 hours and eventually failed, off-scale low, on the 17th visit day. This anomaly is discussed in detail in section 17.1.5.

7.6 GUIDANCE AND NAVIGATION

The performance of the guidance, navigation, and control system was normal. At the completion of the launch phase, the onboard computer indicated an orbit of 225.7 by 153.9 kilometers had been achieved. Analysis of launch data indicates insertion errors of plus 1.59, minus 3.54, and minus 0.94 meters per second in spacecraft X, Y, and Z axes, respectively. These compare favorably with previous missions and indicate normal performance during the launch phase.

Just prior to the first phasing maneuver, the crew reported that the optics were uncontrollable during the star check which was performed prior to ignition. A star check is accomplished by manually driving the optics to a ground-specified shaft and trunnion angle and confirming that the star was within the field of view. A satisfactory star check confirms that the vehicle is at the proper attitude for the maneuver. The optics were uncontrollable in all of the three selectable drive rates. The optics performed normally following the phasing maneuver. The cause of the problem was a combination of a procedural deviation and a design change.

The design change was made during the Apollo program to incorporate a rate-aided-optics drive feature to assist the astronaut during lunar orbit landmark tracking. The change connected the output of the digital-to-analog converter to the motor drive amplifier during the optics manual mode. The computer uses the digital-to-analog converter to issue two types of signals. Alternating current outputs are used for optics drive commands and the direct current outputs are used for service propulsion system engine gimbal drive commands. The type of output is controlled by relays which change in response to discrete signals issued by the computer. The rate-aided-optics feature combined manual commands with computer commands, using the digital-to-analog converters in the optics manual mode. The rate-aided feature is not available in the Skylab computer programs; however, the hardware is still wired for this feature. During the main engine thrusting computer program, the computer issues a discrete signal (disengage optics digital-to-analog converter) to configure the system for engine gimbal control. This discrete, in addition to configuring the digital-to-analog converters, also switches relays in the optics electronics that changes the feedback loop from a velocity type to an acceleration type. Before the design change, the discrete could not have switched the relays in the manual mode; however, now, anytime the optics are in the manual mode and the computer discrete is issued, the feedback loop of the optics will not be configured properly and the optics will not be controllable. The crew deviated from normal procedures by performing the star check later than normal during the pre-ignition checklist. The computer issues the discrete during the thrusting program, at the time that the astronaut exercises an option to perform a gimbal drive test. If the optics are used after the gimbal drive test option, and prior to exiting the thrusting program, the optics will be uncontrollable.

Table 7-II summarizes the platform alignments and table 7-III summarizes the maneuvers during the visit. The spacecraft control configuration was modified because of the reaction control system quad failures discussed in section 7.7. Sufficient control authority existed in all axes to adequately control the spacecraft and the crew reported no difficulty in performing any maneuvers. The single deorbit maneuver was performed in the modified control configuration with normal results.

During the command module/service module separation sequence, unexpected vehicle attitude excursions of 0.19 radian yaw left and 0.07 radian pitch down were experienced. The reaction control system thruster inhibit switches were not configured in accordance with the checklist. This inhibited automatic attitude control and the crew had to manually control the vehicle using the direct switches. Once control of the vehicle was regained, the configuration error was corrected and no further problems were encountered during entry. The cause of the unexpected attitude excursions is not known. A detailed analysis of the separation dynamics was hampered because the telemetry system was configured in low-bit-rate

TABLE 7-II.- PLATFORM ALIGNMENT SUMMARY

Time, Day:hr:min:sec	Program option	Star	Gyro torquing angle, rad			Star angle difference, rad	Gyro drift, meru		
			X	Y	Z		X	Y	Z
209:12:07:07	3	33 Antares, 37 Nunki	0.0	0.4	2.0	0.0	-	-	-
209:12:14:39	2	33 Antares, 37 Nunki	5.3	5.8	-2.2	0.0	-	-	-
209:13:43:46	3	37 Nunki, 45 Fomalhaut	0.2	-3.0	0.4	0.2	-0.40	0.76	1.17
209:15:04:44	3	34 Atria, 41 Dabih	0.3	-6.4	-0.1	0.0	-0.99	1.83	-0.15
209:22:50:00	3	3 Novi, 4 Achernar	0.7	-2.2	1.0	0.0	-0.33	1.10	0.48
210:12:48:00	3	2 Diphda, 4 Achernar	2.4	-3.4	0.5	0.0	-0.66	0.93	0.14
210:15:23:00	3	46 Sun, 14 Canopus	0.2	0.0	-0.2	1.6	-0.34	0.03	-0.23
263:12:11:30	1	(a)	-0.8	-1.3	1.3	0.0	-	-	-
263:13:49:22	3	2 Diphda, 4 Achernar	2.3	-0.0	-0.9	0.0	-5.46	0.08	-2.08
267:12:53:00	1	(a)	2.8	1.1	12.1	0.0	-	-	-
267:17:10:50	3	2 Diphda, 6 Acamar	5.5	-0.8	-1.6	0.0	-4.86	0.71	-1.46
258:09:12:00	3	2 Diphda, 6 Acamar	-0.6	-2.2	1.3	(a)	0.13	0.51	0.30
268:10:37:46	3	2 Diphda, 6 Acamar	-0.9	-2.4	1.4	0.0	0.21	0.53	0.30
268:15:27:45	3	2 Diphda, 6 Acamar	-0.8	-0.7	0.8	(a)	0.61	0.54	0.65
268:18:02:58	3	2 Diphda, 6 Acamar	-1.2	-0.5	-0.1	(a)	1.70	0.77	-0.08

[a]Data not available.

TABLE 7-III.- MANEUVER SUMMARY

Parameter	First phasing	Second phasing	Corrective combination	Coelliptic	Terminal phase initiation	Deorbit
Time[a]						
Ignition, G.m.t.	209:13:28:56.00	209:15:44:44.99	209:16:30:53.40	209:17:07:53.41	209:18:27:25.57	268:21:38:18.07
Cutoff, G.m.t.	209:13:29:05.71	209:15:44:52.12	209:16:30:54.96	209:17:07:54.41	209:18:27:26.41	268:21:38:36.92
Duration, sec	9.71	7.13	1.56	1.00	0.84	18.85
Velocity, meters/sec						
X-axis	65.47	47.37	11.43	5.67	5.76	-132.25
Y-axis	0.00	-4.57	0.12	2.96	-0.12	
Z-axis	0.00	0.00	0.73	0.18	2.99	36.33
[b]Residuals, meters/sec (before trim)						
X-axis	-0.03 (-0.1)	-0.06 (-0.2)	0.12 (0.4		-0.18 (-0.6)	-0.43 (-1.4)
Y-axis	0.15 (0.5)	0.15 (0.5)	-0.03 (-0.1)		0.09 (0.3)	-0.09 (-0.3)
Z-axis	0.24 (0.8)	0.19 (0.6)	-0.09 (-0.3)		0.03 (0.1)	0.03 (0.1)
[b]Residuals, meters/sec (after trim)						
X-axis			-0.06 (-0.2)	0.0 (0.0)		-0.03 (-0.1)
Y-axis	No trim	No trim	-0.03 (-0.1)	-0.03 (-0.1)	No trim	-0.03 (-0.2)
Z-axis	No trim	No trim	0.00 (0.0)	-0.03 (-0.1)	No trim	0.06 (0.2)

[a]Greenwich mean time is shown in day-of-the-year, hours, minutes and seconds.

[b]Residuals are shown in feet per second, as displayed to the crew, in parentheses.

data mode. All system performance before and after the event was normal and a postflight check of the reaction control system thrusters showed normal operation.

The spacecraft was guided to a successful landing at 30 degrees 47 minutes north latitude, 120 degrees 32 minutes west longitude as indicated by the onboard computer.

7.7 PROPULSION

7.7.1 Service Propulsion System

The service propulsion system operations were normal. Six maneuvers were accomplished with a total firing duration of 39 seconds. Five of the maneuvers were performed for rendezvous with the Orbital Workshop. The total firing duration for these five maneuvers was approximately 21 seconds.

During the docked period, system parameters were normal. On visit day 59, the indicated tank pressure shifted approximately 17.24 newtons per square centimeter downward. This shift was attributed to a faulty signal conditioner. Section 17.1.7 contains a discussion of this anomaly.

7.7.2 Service Module Reaction Control System

Prelaunch servicing was normal except the propellant samples taken from the servicing ground support equipment prior to loading in the spacecraft showed a slight out-of-tolerance condition on particle count and size. A few particles were found that exceeded both the allowable size and number. Chemical analysis of the potential effects of the condition indicated no potential flight problems and a waiver was approved. The propellant loads were normal and are shown in section 7.10.2.

The systems were activated before lift-off by filling the propellant manifolds using propellant from the propellant storage module. Systems pressures and temperatures were normal at this time. The systems were first used during the separation maneuver from the launch vehicle and were configured to feed propellant from the quad propellant tanks to increase the quad ullage volumes prior to switching to the propellant storage module. The quad A engines were switched to use propellant storage module propellants with 115.21 kilograms of usable quad propellants remaining. Quad B was isolated before being switched. Quad C was switched with 121.56 kilograms remaining and quad D was switched with 82.1 kilograms remaining. System data during the first use of the system were normal.

Approximately 3 hours into the mission, the quad B helium source pressure and propellant utilization data indicated an abnormal propellant usage. These data, together with the spacecraft rate data and manifold pressure data, gave positive indications that the positive yaw (B-3) engine was leaking oxidizer. The crew also reported a "snow storm" on the right side (quad B side) of the spacecraft at the same time. Quad B was isolated from the rest of the system about 3 hours after lift-off. Details of this anomaly are given in section 17.1.1.

At 10:47 G.m.t., on the sixth visit day, the quad D engine package temperature had decreased sufficiently to cause a caution and warning alarm. Service module propellant pressures and system temperatures indicated that oxidizer was venting within the quad D engine housing. The quad was isolated about 1 hour and 20 minutes later by closing the propellant isolation valves. Details of this problem are given in section 17.1.2.

Rules were established as a result of these problems to limit the use of quads B and D to emergency attitude control, emergency translation capability (assumes a service propulsion system and either a quad A or C failure), and during the command module/service module separation maneuver (service module jettison controller function).

The quad A and C engines were used for attitude control and for backup deorbit capability after separation from the Orbital Workshop. Both quad A and C and the propellant storage module propellant feed systems were used during this period. Systems data verified normal performance up to loss of data at command module/service module separation. Propellant usage data are shown in section 7.10.2.

On visit day 9, the crew was requested to reconfigure the service module reaction control system propellant isolation valves to insure against a single point failure trapping the propellant storage module propellant in the tanks. During this operation, the propellant storage module propellant manifold pressure experienced an unexplained 8.3 newtons per square centimeter drop. This was believed to be caused by a reverse flow leakage through one of the quad C oxidizer isolation valves. This condition did not affect the system's performance.

At about 15:45 G.m.t. on visit day 17, the quad B engine package temperature measurement failed off-scale low. After the failure, heater operation was established by monitoring the electrical bus currents. A discussion of this failure is given in section 17.1.5.

7.7.3 Command Module Reaction Control System

All of the propellant loadings were normal (see section 7.10.2). The system helium pressures and temperatures were normal throughout the quiescient portions of the visit. Changes in system pressures noted were a result of system temperature changes.

Checks of the engine valve temperatures prior to command and service module/Saturn Workshop undocking showed acceptable temperatures ranging from 275° to 302° K. No preheating was required prior to system activation.

System activation was accomplished prior to undocking. The activation and entry checks were normal. The command module/service module separation was accomplished normally and the command module reaction control system was used for attitude control until drogue parachute deployment.

The command module reaction control system was reported to be in a normal condition after landing and command module recovery by the prime recovery ship team. The systems were depressurized normally onboard the recovery ship. System safing, propellant offloading, and system decontamination was accomplished normally.

7.8 ENVIRONMENTAL CONTROL SYSTEM

The environmental control system performed satisfactorily during the command and service module active and quiescent phases of the mission. Several failures and minor operational discrepancies were noted, but none had any significant consequences.

During the potable water chlorination procedures, after the post-sleep activities on the second visit day, the crew reported leakage through the buffer ampule when the refilling operation was attempted. Inspection indicated that the end plate (piston) remained depressed while water leaked through the ampule bag and filled the injector. Apparently, the ampule bag was torn as the buffer was injected. Ampule bag failures have occurred on recent flights, and have only created a nuisance.

The carbon dioxide sensor failed to respond to changes in carbon dioxide level throughout the mission. The sensor output was essentially constant at 0.017 newton per square centimeter from the prelaunch suit loop oxygen purge to spacecraft landing. On visit day 2, the sensor output spiked to 0.144 newton per square centimeter for 1 second and activated the master alarm (trip point was 0.101 newton per square centimeter). The carbon dioxide caution and warning alarm was subsequently inhibited. Section 17.1.8 contains a discussion of this anomaly.

After the environmental control system was configured to the quiescent mode and the primary coolant system temperatures had stabilized, data indicated that the primary water/glycol accumulator quantity was decreasing at a rate of about 1 percent per day, indicating a leak. On visit day 22, the accumulator quantity was adjusted from 26 percent to about 50 percent with coolant from the reservoir. Accumulator quantity decay continued, but at a reduced rate of about 1/2 percent per day. During the 7-day check on visit day 27, the Commander found about one-third of a pint of liquid by panel 382 in the command module. The water/glycol accumulator quantity stopped decreasing on visit day 31, and there was no further indication of leakage through the end of the visit. Section 17.1.6 contains a discussion of this anomaly.

The crew reported that upon opening the postlanding ventilation valves after reaching stable I condition, the cabin pressure decreased, a vapor cloud occurred, and a small amount of water came in the postlanding ventilation valves. At approximately 800 feet during descent, the procedures require the cabin pressure relief valves to be closed and, if the crew is suited, the direct oxygen valve opened. The postlanding inspection revealed that the direct oxygen valve was approximately 40 percent open and the surge tank was empty, consequently, the crew may have incorrectly opened the direct oxygen valve and pressurized the cabin slightly above ambient. Had this condition occurred, upon opening the postlanding ventilation valves, the cabin would have depressurized. Depending on the cabin pressure, temperature, humidity, and the atmospheric temperature and humidity, a cloud of water vapor could have occurred in the cabin at depressurization. The data are not available to fully assess this possibility. Also, the construction of the command module forward deck and the interface of the postlanding valves allows a small amount of water to collect at the valve openings and when the valves are activated, the water will enter the cabin.

7.9 SPECIAL STOWAGE

Replacement items and additions were stowed in the second visit command module for a variety of reasons. These were to replace failed or degraded equipment; to replace items with improved designs; to provide for an extended mission; to provide for changes in planned activities; to replenish supplies being depleted due to usage rates greater than anticipated; to replace lost items; to provide items for crew comfort; and to provide for improvements in communications, television, and photography. Also, there were some items that were originally scheduled for first visit stowage that were held over for the second visit because of stowage priorities. Approximately 15 percent of the special stowage items were the result of the heat damage problem. Changes to the launch stowage

configuration resulted in a gain of 166.83 kilograms of stowage weight. Command module weight and center of gravity for launch are shown in table 7-IV.

All available second visit command module stowage locker space was used. In addition, the following items were stowed on top of the aft bulkhead lockers: a parasol sun shield of improved design, a rate gyro package, and crewmen boots. The stowage arrangement is shown in figure 7-1 for the launch configuration and in figure 7-2 for the return configuration.

7.9.1 Launch Stowage Relocations

Deviations from the planned stowage caused considerable relocating of command module stowage items. The crew was briefed on all changes as the items were repositioned. Training hardware was used to demonstrate the packaging and stowage feasibility. Couch stroking envelopes resulting from worst-case land and water landing are shown in figure 7-3. The following table shows the functional areas from which the launch stowage configuration changes emanated.

Area	Weight, kilograms	$\bar{X}$ axis, centimeters	$\bar{Y}$ axis, centimeters	$\bar{Z}$ axis, centimeters
Second visit baseline launch stowage	728.91	2636.95	5.28	1.30
Operational additions	182.50	2586.08	-6.02	25.86
Science additions	90.73	2582.14	22.96	8.41
Operational deletions	-102.84	2581.71	31.85	12.88
Science deletions	-10.15	2656.18	-42.67	28.22
Miscellaneous additions	6.58	2586.48	0.00	-12.45
Actual launch stowage	895.73	2623.87	1.14	0.84

7.9.2 Return Stowage

The majority of the additions for return stowage were added for post-flight analysis purposes. Nine delivered items were deleted from the return stowage list. The following table shows the functional areas from which the return stowage changes emanated.

Area	Weight, kilograms	$\bar{X}$ axis, centimeters	$\bar{Y}$ axis, centimeters	$\bar{Z}$ axis, centimeters
Second visit baseline return stowage	790.05	2623.19	3.20	2.92
Operational additions	14.65	2583.36	6.78	-15.70
Science additions	38.71	2594.79	-4.06	53.87
Operational deletions	-16.61	2592.37	56.34	26.37
Science deletions	-7.70	2619.50	-54.64	27.86
Miscellaneous additions	5.68	2586.48	0.00	-12.45
Actual return stowage	824.78	2620.92	0.36	3.78

7.9.3 Stowage Differences

The second visit launch and return stowage differences from the nominal configuration are listed in tables 7-V and 7-VI.

TABLE 7-IV.- COMMAND MODULE WEIGHT AND CENTER OF GRAVITY

Item	Actual	Limit
Earth launch weight, kilograms	6085	6124
Z-axis center of gravity at earth launch, centimeters . . .	9.19	8.94
X-axis center of gravity at high altitude burnout, centimeters	2847.85	2847.34
Descent or main parachutes weight, kilograms	5854[a]	5897[a]
Landing weight, kilograms	5612	5659

[a]The weights are applicable to a high altitude abort case with the command module in the launch configuration.

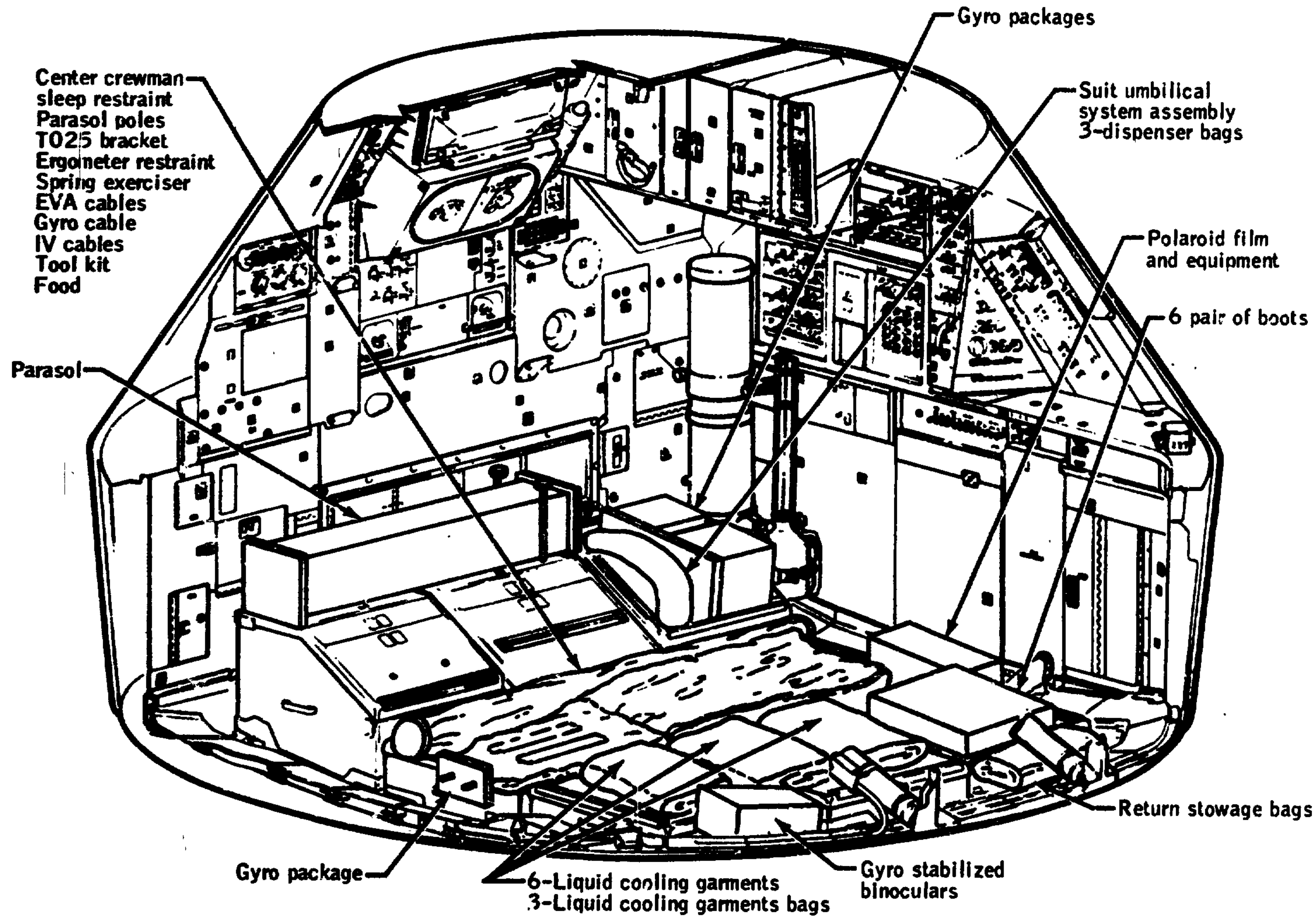


Figure 7-1.- Second visit launch stowage configuration.

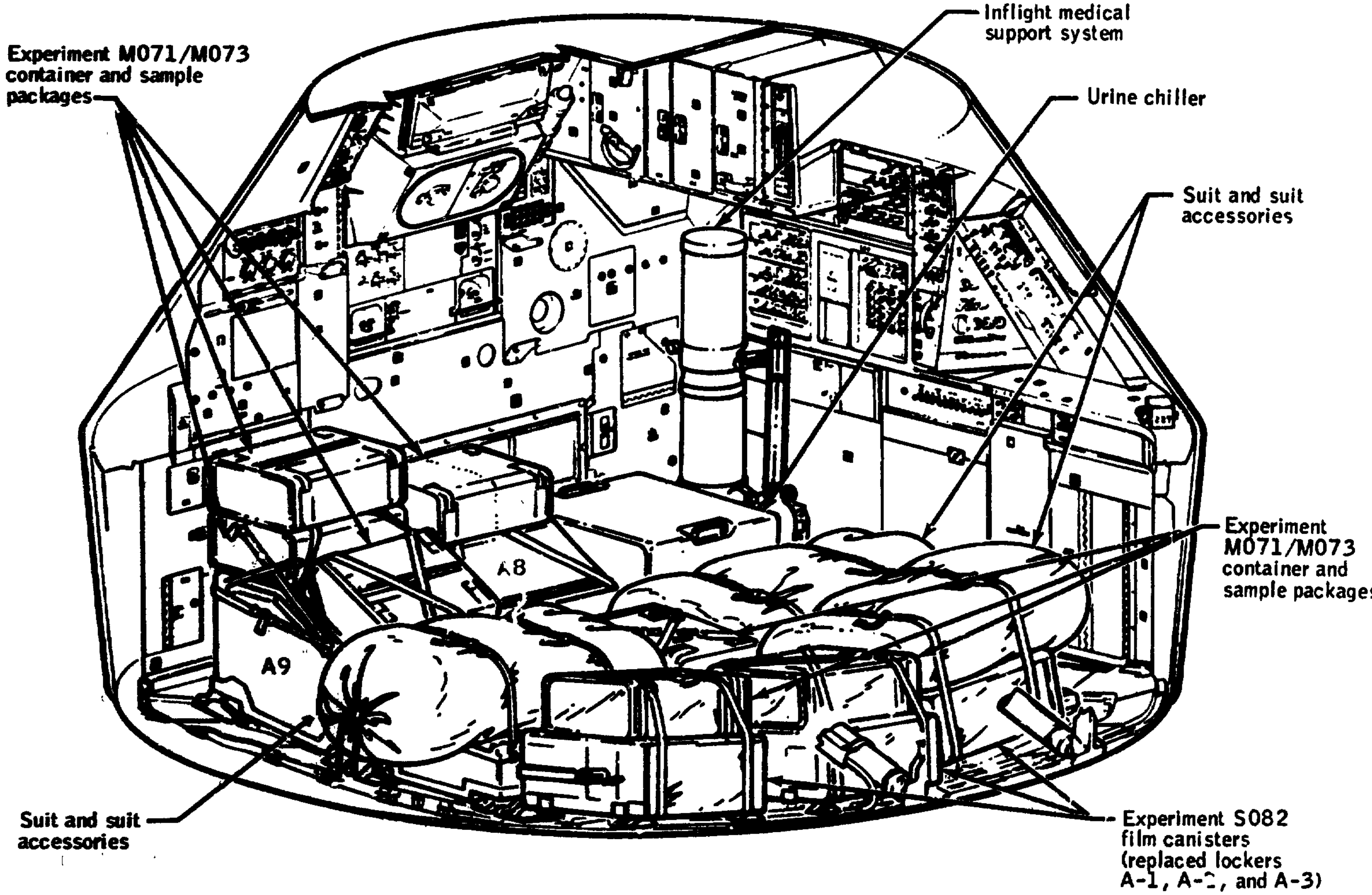
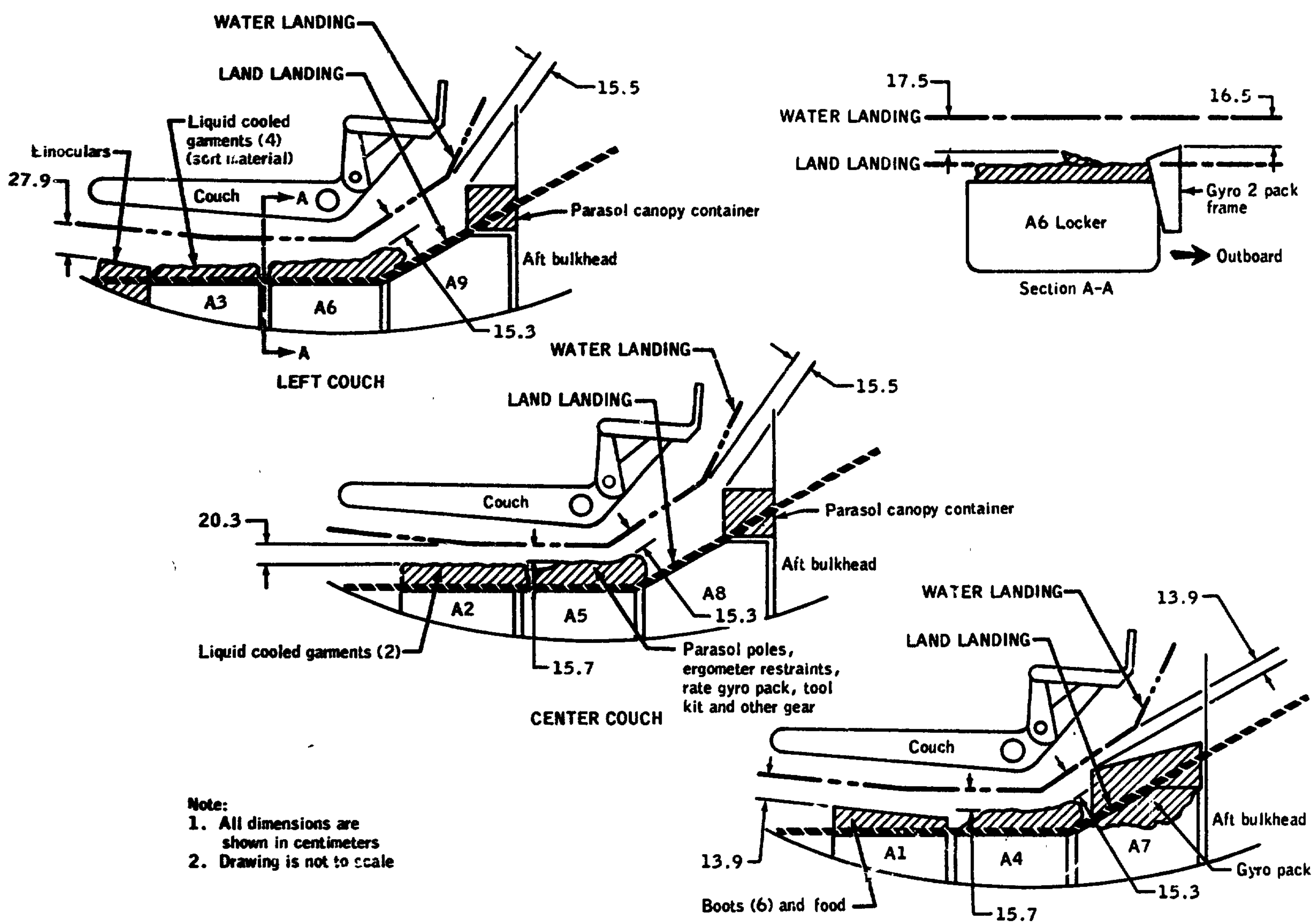


Figure 7-2.- Second visit return stowage configuration.



Note:
1. All dimensions are shown in centimeters
2. Drawing is not to scale

Figure 7-3.- Second visit landing attenuation envelopes.

TABLE 7-V.- SECOND VISIT LAUNCH STOWAGE DIFFERENCES

Item	Reason
Additions	
A2 locker bag	To provide stowage space for loose items in A2 locker
Modified boots (12 pair)	To replace crew boots having worn toes
Urine collection transper assembly with bags, clamps and hose adapter (3)	To replace first visit usage
Personal hygiene resupply kit	Resupply due to heat damage
35-mm flash battery bag	Camera battery replacement assembly
General purpose tape (2)	Anticipated usage was exceeded
Hasselblad fuse package	To replace blown camera fuse
Water dispenser valve assembly (2)	To replace failed valve
Rubber band package, large (4)	Anticipated usage was exceeded
Inflight medical support system cans A and B	Drug resupply due to heat damage
Food resupply pack, catsup (3)	Resupply due to heat damage
AM tape recorder (2)	To replace failed unit
Triangular shoes modification kit	To repair worn shoes toes
Bungee cord (12)	Anticipated usage was exceeded
Television camera, with lens port cover	To replace failed unit

TABLE 7-V.- SECOND VISIT LAUNCH STOWAGE DIFFERENCES - Continued

Item	Reason
Television lens, with caps	To replace failed component
Disposal bag, E699 (17)	Anticipated usage was exceeded
Waste management compartment, foot restraints (4)	Design improvement item
Double clipboard tethers (2)	Design improvement item
Earth Resources Experiment Package book tether (2)	Design improvement item
Tool ratchet handle	To replace broken component
Inflight medical support system heat sink	To replace unscheduled usage
Locker door decals	To allow relabeling of lockers to reflect crew changes
Iodine tablet package assembly	To replace broken item
Medical injector	To replace item inadvertently returned by first visit crew
Suit umbilical system: loop heater, flexible hose (2), power cable, and control box	To replace failed components
Coupling and expander for wardroom window	To defrost window
Airlock module vent valve Screen	To replace failed component
Calibration cartridge for carbon dioxide detector	To replace failed component
Inflight exerciser, modification kit (2)	Design improvement item

TABLE 7-V.- SECOND VISIT LAUNCH STOWAGE DIFFERENCES - Continued

Item	Reason
Rate gyro package: distributor, bracket with rate gyro processor (2), L-shaped rate gyro processor (4), intravehicular activity cable set, test cable assembly, tool kit, and extravehicular activity cable assembly	To replace failed components
Electrical power controller derived rate control assembly: cable, 30.5 centimeters; cable, 45.7 centimeters; and connector tool with bag	Required for Apollo Telescope Mount pointing
Tongue depressor	To replace lost item
Vitamin pill vial	To replace broken item
5-mm lens for the 16-mm data acquisition camera	To allow close-up photography
Velcro kit	To replace peeled velcro retention
Wardroom foot restraint	Design improvement item
Sphygmomanometer	To replace item returned by first visit crew
Stethoscope, with bag	To replace item returned by first visit crew
Science demonstration package	To demonstrate zero-g phenomena
Skylab parasol assembly	For thermal control
Skylab parasol access	For thermal control

TABLE 7-V.- SECOND VISIT LAUNCH STOWAGE DIFFERENCES - Continued

Item	Reason
35-mm film cassettes (7)	To photograph targets of opportunity
70-mm film magazine (3)	To photograph targets of opportunity
Capture latch release tool	To open the command module hatch
Multimeter and pin adapter	For rate gyro electrical circuit check
Command module umbilical tether	For contingency standup extravehicular activity
Polaroid camera bracket, with bag; persistent image scope, with bag; polaroid camera, with shield; lens and bag, and polaroid film (26)	For Apollo Telescope Mount pointing
Swiss army knife, with pouch	To replace lost item
Haze filter for 300-mm lens	To photograph targets of opportunity
Wrist tether (3)	For use during thermal sail deployment
Friction ring package for thermal sail	For thermal sail deployment
Flight data file update	To provide for previously unforeseen requirement
Shirts, socks and underwear	For crew comfort
Hardware kit: nuts and bolts	For miscellaneous repairs
Dynamic exerciser	To increase crew exercise capability

TABLE 7-V.- SECOND VISIT LAUNCH STOWAGE DIFFERENCES - Continued

Item	Reason
Gyro-stabilized binoculars	To observe targets of opportunity
Haze filter for 70-mm camera	To photograph targets of opportunity
Parasol fabric sample	To evaluate environmental degradation of the parasol material
Hand-held microphone assembly	To improve communications
Water service quick disconnect	For contingency command module water dump
Chest exerciser	To increase crew exercise capability
Food spice kit	To improve palatability of food
Aftershave lotion (3)	By crew request
Food package (3)	For three-day mission extension
Experiment S019, film canister	To extend experiment capability
Experiment M072, modified specimen mass measurement device	To replace failed electronics package
Experiment S190B, earth terrain camera vacuum seal assembly	To replace failed component
Earth Resources Experiment Package magnetic tape reel (2)	Resupply due to heat damage
Mechanical seeder (ED 61/62)	Resupply due to heat damage

TABLE 7-V.- SECOND VISIT LAUNCH STOWAGE DIFFERENCES - Continued

Item	Reason
Experiment S082A, film magazine, extreme ultraviolet	To replace failed component
Experiment M092, leg volume measuring band (4)	To accomodate size of crew's legs
Experiment M172, food tray spring clip (8)	Design improvement item
Experiment M172, battery restraint spring assembly (2)	Design improvement item
Experiment M133, tape canister and two tapes	Resupply due to heat damage
Experiment M509, battery voltmeter adapter	To check batteries
Experiment M171 ergometer, restraint modification	Design improvement item
Experiment M131, rotating litter chair modification kit	Design improvement item
Experiment S054, drive motor circuit breaker protective bracket	To replace failed component and provide rate tyro package circuit protection
Experiment S192, gage, scribe and shim	To correct experiment misalignment
Experiment S230, calibration shield (2)	To recalibrate experiment
Experiment T027/S073, jumper cable and tool	To replace failed cable/connector assembly
Experiment S015 and support hardware	To provide experiment hardware which was was deleted from the first visit because of weight limitations

TABLE 7-V.- SECOND VISIT LAUNCH STOWAGE DIFFERENCES - Continued

Item	Reason
Experiment S149; crank handle, rod, clamp, extravehicular activity extender, and end attachment	To deploy experiment during extravehicular activity
Experiment S063 adapter	To provide solar-side scientific airlock data
Experiment T025: adapter, f-stop tab, protector cover, remote control cable, and thermal blanket for 35-mm camera	To allow use of camera during extravehicular activity
Deletions	
Intravehicular activity umbilical and gage	Anticipated replacement no longer required
Secondary oxygen pack and container	Anticipated replacement no longer required
Pressure control unit (2)	Anticipated replacement no longer required
Pressure control unit container (2)	Anticipated replacement no longer required
Liquid cooling garment (5)	Anticipated replacement no longer required
Fecal containment subsystem (5)	Anticipated replacement no longer required
Carbon dioxide absorber element (4)	Anticipated replacement no longer required
Boots (3 pair)	Regular boots, replaced by modified boots, listed elsewhere
Locker A1	Removed to permit stowage for experiment S082A

TABLE 7-V.- SECOND VISIT LAUNCH STOWAGE DIFFERENCES - Concluded

Item	Reason
Carbon monoxide monitor assembly	Anticipated requirement no longer existed
Experiment S020 film container, with cushion	Capability no longer exists
35-mm film cassettes (13)	For use with experiments S063 and T025
Experiment S183 film container	To replace failed unit
Locker B6	To accomodate the S015 experiment hardware

TABLE 7-VI.- SECOND VISIT RETURN STOWAGE DIFFERENCES

Item	Reason
Additions	
Polaroid pictures of solar television monitor	To allow scientific analysis of data
Liquid cooling garment	To allow evaluation of leaking condition
Experiment ED52 carrying case, with spider	To allow further spider web studies
Hemoglobinometer and urine refractometer	To recalibrate before use on third visit
Sample food	For analysis of heat effects
Contingency fecal bag (3) and perspiration samples (6)	For medical analysis
Experiment M092 leg band	To allow evaluation of failed component
Contingency fecal bag (4)	For stowage of small parts
Tape recorder printed circuits	To allow evaluation of failed component
AM tape recorder belt (2)	To allow evaluation of failed component
Carbon dioxide passive filter inlet (2)	To allow evaluation of failed component
Experiment S055 door ramp	To allow evaluation of failed component
Experiment M553 sphere forming	Experiment was completed on second visit

TABLE 7-VI.- SECOND VISIT RETURN STOWAGE DIFFERENCES - Continued

Item	Reason
Experiment M479/M553 hatch view port shield and camera port shield	Part returned for analysis
Experiment M518 cartridge container B with 15 cartridges	Experiment was completed on second visit
Experiment M518 cartridge container A with 15 cartridges	Experiment was completed on second visit
Orbital Workshop television camera power cable	To allow evaluation of failed component
Parasol material sample	To evaluate environmental degradation of parasol material
Experiment S228 detector	For ground analysis of component
Clothing module log cards	To allow evaluation of usage
Command module water servicing quick disconnect	Inadvertently omitted from stowage list
Experiment S190A film cassette	To return for film analysis
Inflight medical support system canister with fish	For additional scientific evaluation of subject
Command and service module guidance and control checklist and systems checklist	Inadvertently omitted from stowage list
Locker A3	To replace locker A4 per rate gyro processor
Experiment S019 film canister	Experiment data
Experiment S015 package	Experiment data

TABLE 7-VI.- SECOND VISIT RETURN STOWAGE DIFFERENCES - Concluded

Item	Reason
Deletions	
Experiment S183 film carousel	Was not launched
Television camera front lens cover	Shortage of return space
Television camera rear lens cover	Shortage of return space
Television camera zoom lens	Shortage of return space
Television monitor	Shortage of return space
Experiment M555, specimen cushion with bag	To save weight
Locker A4	Lid removed before launch
Locker B6	Make room for experiment S015
Experiment S020 film canister	Not launched

7.10 CONSUMABLES

The command and service module consumable usage during the second visit was maintained well within the redline limits. Specific system usage is discussed in the following paragraphs.

7.10.1 Service Propulsion System

The service propulsion system propellant and helium loadings and consumption values are listed in the following table. The loadings were calculated from gaging system readings and measured densities prior to lift-off.

Condition	Propellant, kilograms		
	Fuel	Oxidizer	Total
Loaded	867	1398	2265
Consumed	430	691	1121
Remaining	437	707	1144

Condition	Helium, kilograms	
	Storage bottles	Propellant tanks
Loaded	19.3	14.2
Used	1.9	-1.9
Remaining	17.4	16.1

7.10.2 Reaction Control System Propellant

Service module.- The propellant utilization and loading data for the service module reaction control system were as shown in the following table. Consumption was calculated from telemetered helium tank pressure histories and was based on pressure, volume, and temperature relationships.

Condition	Propellant, kilograms		
	Fuel	Oxidizer	Total
Loaded			
Quad A	49.9	101.9	151.8
Quad B	49.9	102.2	152.1
Quad C	49.9	100.9	150.8
Quad D	50.0	101.3	151.3
Propellant storage module	228.3	458.1	686.4
Total			1292.4
[a]Usable loaded			1180.3
Consumed			348.4
Remaining at command module/service module separation			831.9

[a]Usable propellant is the amount loaded minus the amount trapped with corrections made for gaging system errors.

Command module.- The loading of command module reaction control system propellant was as follows:

Condition	Propellant, kilograms		
	Fuel	Oxidizer	Total
Loaded			
System 1	19.8	41.0	60.8
System 2	19.6	41.0	60.6
Total	39.4	82.0	121.4
Consumed			23.6[a]

[a]Based on amount of propellant off loaded.

7.10.3 Cryogenic Storage System

The total cryogenic hydrogen and oxygen quantities available at lift-off and consumed during the flight are as follows. Consumption values were based on quantity data transmitted by telemetry.

Condition	Hydrogen, kilograms	Oxygen, kilograms
Available at lift-off		
Tank 1	11.6	147
Tank 2	11.6	114
Total	23.2	261
Consumed		
Tank 1	11.6	93.6
Tank 2	11.6	102.1
Total	23.2	195.7
Remaining at fuel cell shutdown		
Tank 1	0	53.4
Tank 2	0	11.9
Total	0	65.3

7.10.4 Water

The water quantities loaded, produced, and expelled during the mission are shown in the following table.

Condition	Quantity, kilograms
Loaded (at lift-off)	
Potable tank	6
Waste tank	8
Produced in-flight	
Fuel cells	218
Lithium hydroxide canister	2
Metabolic activity	4
Total loaded and produced	238
Stored in Orbital Workshop	22
Lost as urine	9
Evaporator usage	10
Remaining at command module/ service module separation	
Service module tank	157
Potable tank	16
Waste tank	10
Total expelled and remaining	224
Balance	14[a]

[a]Value added to compensate for the inaccuracies of the transducers and uncertainty of the data.

8.0 CREW EQUIPMENT

8.1 EXTRAVEHICULAR MOBILITY UNIT

The extravehicular mobility units performed satisfactorily. The extravehicular mobility units, in whole or in part, were used in the following activities:

a. Launch and boost phase - visit day 1

b. First extravehicular activity - visit day 10

c. Experiment M509 (suited run) - visit day 21

d. Second extravehicular activity - visit day 28

e. Experiment T020 (suited run) - visit day 48

f. Cooling evaluation for third extravehicular activity - visit day 50

g. Third extravehicular activity - visit day 57

h. Undocking preparations

All three crewmen were connected to the suit umbilical system 1 water loop during the first extravehicular activity. Both Airlock Module primary coolant loop pumps were operated to provide greater heat removal capability. Water was delivered to the liquid cooling garments at 285.4° to 287° K. The average calculated heat load rates during the extravehicular activity were 306.7 watts for extravehicular crewman 1 (Scientist Pilot) and 298.3 watts for extravehicular crewman 2 (Pilot). The Pilot increased his water diverter valve setting once at the ground's suggestion when telemetry data indicated the heat load in the gas system was high. The extravehicular mobility unit pressures were maintained throughout the extravehicular activity at about 2.46 newtons per square centimeter for the Scientist Pilot and 2.42 newtons per square centimeter for the Pilot. During status checks, both crewmen reported 2.48 newtons per square centimeter cuff gage readings. The duration of the first extravehicular activity was 6 hours and 29 minutes.

The extravehicular mobility unit performance was normal during the suited experiment M509 (Astronaut Maneuvering Equipment) operation. The first set of maneuvers was conducted with cooling and life support oxygen supplied through the life support umbilical. The life support umbilical was then disconnected and oxygen was supplied from the secondary oxygen

pack. The secondary oxygen pack was used to depletion and lasted between 19 and 20 minutes. The life support umbilical was reconnected for the remaining maneuvers. The suit pressure, while on the life support umbilical, was maintained at 2.52 newtons per square centimeter. During maneuvers with the life support umbilical attached, the inertia of the umbilical greatly affected the operation of the astronaut maneuvering unit. The duration of the intravehicular activity, from donning station egress to station ingress, was 1 hour and 56 minutes.

Because of the loss of fluid in the Airlock Module primary coolant system, all three crewmen were connected to suit umbilical system 2 water loop and the secondary coolant system was operated with two pumps during the second extravehicular activity. Water was delivered to the liquid cooling garments at 285.4° to 287° K. The average calculated heat load rates during the extravehicular activity were 291.2 watts for the Pilot (the Pilot performed the gyro-cable installation) and 294.0 watts for the Scientist Pilot (the Scientist Pilot performed all other extravehicular activity tasks). The extravehicular mobility unit pressures were maintained at the same levels as the previous extravehicular activity. The duration of the extravehicular activity was 4 hours and 30 minutes. During the post-extravehicular activities, the Commander reported that one of the tubes in the liquid cooling garment was leaking. This liquid cooling garment was returned for postflight analysis. See section 17.3.2 for a discussion of this anomaly.

The extravehicular mobility unit performance was normal during the suited experiment T020 (Foot Controlled Maneuvering Unit) activity. Prior to this activity, a life support umbilical had been stripped to leave only the oxygen hose. This resulted in negligible life support umbilical inertia effects on the maneuvering unit. Some of the maneuvers were performed on only the secondary oxygen pack (life support umbilical disconnected). The secondary oxygen pack was used until a pressure of 1379 newtons per square centimeter was reached.

After the second extravehicular activity, the Airlock Module secondary coolant system was not modulating properly. As a result, gas cooling was to be used during the third extravehicular activity by the three crewmen. However, the normal gas cooling procedure was not desirable for extravehicular crewman 3 (Pilot) in the Multiple Docking Adapter because this would dump excessive gas into the Multiple Docking Adapter. A test was conducted by the Pilot to evaluate a method of drawing air through the open suit using a power module blower and the suit drying hose. The Pilot believed that drawing air through the neck ring and out the suit oxygen outlet port would be marginal but adequate for metabolic cooling. The method of blowing air into the suit and out through the neck ring was also evaluated, but the first method proved best, confirming ground test conclusions.

The extravehicular crewmen reported that gas cooling was adequate for the third extravehicular activity because of the low work rates. The average metabolic rate for extravehicular crewman 2 (Commander) was calculated as approximately 268.4 watts, based on oxygen gas temperatures. A reliable analysis of the metabolic rate for extravehicular crewman 1 (Scientist Pilot) at the fixed airlock shroud was not possible because of the low work rate and the length of life support umbilical stowed in the airlock, but an average metabolic rate was estimated to be 208.0 watts. The extravehicular mobility unit pressures were consistently maintained at about 2.42 newtons per square centimeter for the Commander and 2.46 newtons per square centimeter for the Scientist Pilot. During status checks, the Commander reported 2.52 newtons per square centimeter and the Science Pilot reported 2.55 newtons per square centimeter cuff gage readings. The duration of the third extravehicular activity was 2 hours and 41 minutes.

8.2 CREW PERSONAL EQUIPMENT

The crew was satisfied with their personal items. Garments were satisfactory in terms of both fit and comfort. Quantities were sufficient, with the exception of socks. Additional socks are being supplied to allow a daily change.

The crew used very little of their off-duty activities equipment except for their tape recorders. The crew reported an inability to cut off the speakers when the earphones were used. Procedures for achieving private listening were transmitted to the crew, as well as techniques for cleaning the capstan roller to achieve better fidelity.

Fogging of the goggles contained in the experiments T020/M509 head protective assembly occurred. This was alleviated by use of the antifogging solution stowed in the Orbital Workshop extravehicular mobility unit maintenance kit.

The crew, in order to free their hands during work periods, evaluated the head-mounted light stowed with the inflight medical support system equipment and were satisfied with the results.

9.0 BIOMEDICAL

9.1 INTRODUCTION

This section contains a preliminary evaluation of the biomedical aspects of the preflight, inflight, and immediate postflight phases of this 59-day visit. Each crewman is officially credited with 1427 hours and 9 minutes of space flight. Capital letters and italics are used in this section for scientific nomenclature in accordance with government standards.

9.2 FLIGHT CREW HEALTH STABILIZATION

The basic health stabilization program, originally begun on Apollo 14, and modified for the first manned visit to Skylab, was also instituted, with minor changes, during the premission phase of the second visit. The program was in operation from 21 days prior to the launch of the second visit until 7 days following crew landing.

Personnel required to be in personal contact with the crewmen or to work in an area with the crewmen were divided into two groups. Those persons who had to approach the crewmen within 2 meters were identified as class A primary contacts and were required to wear surgical masks when in the presence of a crewman. Others who worked in the area were identified as class B primary contacts. All primary contacts were given a thorough physical examination to ascertain their freedom from infectious diseases. Vaccinations were given to update any required vaccine. The health status of the primary contacts was monitored through a rigid and continuous reporting and medical examination program. Those individuals actively carrying infectious disease agents were not allowed to return to the primary contact areas until they were free of the infectious agents. No infectious diseases were experienced by the crew during the preflight and postflight periods.

9.3 CREW MEDICAL TRAINING

The three crewmen received extensive training in the use of the inflight medical support system. While the original plans called for 6 hours of inflight medical support system emergency equipment training in addition to the clinical medical training, 2 hours were deleted because of the earlier launch date. However, the crew's knowledge of the equipment, especially that of the Scientist Pilot, was adequate. Thorough

training in the use of the therapeutic equipment and medications on board, the crew was considered to be able to treat most minor to moderately severe illnesses or injuries which might occur, and also to stabilize the condition of a crewman should a more serious condition occur. The inflight medical support system was not needed for the treatment of major illnesses, but certain pieces of diagnostic and laboratory equipment were used for the flight-planned experiments discussed in sections 4.2.7, 8.2, 9.4, and 9.5.

9.4 ENVIRONMENT

The Orbital Workshop environment was near the optimal level during the second visit. Until the twin-pole sunshade was deployed, high beta angles produced elevations of temperature in the wardroom and experiment compartment areas as high as 300° K on visit day 4. This elevated temperature caused some difficulty in arranging a comfortable configuration of the sleeping bags during the early portion of the visit, and some difficulty during periods of high work rates when using the ergometer unless a fan was turned directly on the crewman. The Orbital Workshop atmosphere was controlled as follows:

Environment	Maximum	Mean	Minimum
Ambient pressure, newtons per square centimeter	3.86	3.52	3.24
Ambient temperature, °K	298.7	295.9	293.7
Oxygen partial pressure, newtons per square centimeter	2.69	2.41	2.28
Carbon dioxide partial pressure, newtons per square centimeter	0.093	0.067	0.040
Dew point, °K	282	284.3	286.5
Relative humidity, percent	57	46	38

A slightly over-rich oxygen environment of up to 2.7 newtons per square centimeter was provided prior to conducting the crew maneuvering experiments because these experiments increase the atmospheric nitrogen content.

Early in the visit, the crew noticed that the light levels throughout the Orbital Workshop were too low. A flashlight or the medical headlamp was kept at hand to illuminate areas where a detailed examination was necessary. Ambient sound levels were low except when the ergometer was in operation. The use of the communication stations as well as direct communications were difficult during medical experiments or personal exercise periods.

The large space contained within the Skylab cluster offered both mobility and privacy to the crew. Early in the visit, the freedom of motion afforded by this large space may have contributed to the motion sickness that was experienced.

The wardroom food pedestal with its related food appliances and the waste management compartment efficiently provided for the basic biological necessities. The use of the wardroom pedestal as a desk proved it inadequate.

9.5 CREW HEALTH

9.5.1 Preflight Period

The full medical protocol was to have started 60 days prior to flight. The shortened preflight timeline, necessitated by the earlier launch date caused rescheduling of certain medical procedures; however, beginning with 30-day preflight examination, the schedule of examinations proceeded as planned. Results of the preflight series of examinations beginning 5 days prior to flight verified that the crew was in excellent physical health and psychologically ready for the visit. The preflight examinations and history reviews revealed nothing of significance to crew health and safety or the planned operational aspects of the flight.

9.5.2 Inflight Phase

The launch phase of the flight produced a maximum heart rate of 150 beats per minute from the Commander, 138 beats per minute from the Scientist Pilot, and 128 beats per minute from the Pilot. There were no significant arrhythmias or other medical abnormalities. Shortly after orbital insertion, the Pilot began to experience motion sickness. This sickness persisted and was aggravated by movement. One hour after orbital insertion, the Pilot took one anti-motion-sickness capsule, a combination of scopolamine/dextroamphetamine. Relief was obtained from the medication and the Pilot was able to participate in the activation of the Orbital Workshop following docking. The heavy workload necessary to meet the strenuous demands of the activation procedures eventually aggravated

the motion sickness. Following a meal, the Pilot vomited. The vomitus was collected in a plastic bag, weighed, and frozen for return and analysis. The Commander and the Scientist Pilot also experienced some motion sickness during the early phases of Orbital Workshop activation, a condition for which these crewmen also took the anti-motion-sickness capsules. The malaise experienced by all crewmen caused a loss of work time in the first 3 days of the visit until the symptoms subsided. After approximately 2 more days, the crew overcame the residual weakness. The crew activity of visit day 1 lasted approximately 21 hours. Partly because of this long workday and partly because of the motion sickness, the timelines of visit day 2 were eased considerably. Beginning with visit day 3, however, the crew operated essentially on premission timelines, awakening at 11:00 a.m. G.m.t. and retiring at approximately 3:00 p.m. G.m.t.

To reduce stomach awareness and to maintain nutrition, the eating schedules of the flight plan were changed during the first 7 days of the mission, allowing the crew to eat more frequent but smaller meals.

Nasal congestion, which had been noted during the first visit, became very evident on the voice communications between the end of the third day and the early portion of the fourth day. The congestion, barely noticeable to the crewmen themselves, caused no discomfort or operational constraints, but persisted throughout the visit. The condition became less noticeable near the end of the visit. The Scientist Pilot used oxymetazoline on two occasions to determine the effectiveness of this medication in reducing the nasal congestion. Within an hour after landing, no traces of any nasal quality could be detected in the crew's speech.

A circadian shift of 4 hours was made to accomodate the long and arduous deactivation phase. The crew was awakened 2 hours earlier on visit day 51 and again on visit day 53; the crew had retired 1 hour earlier before each of these early awakenings. To assure adequate sleep on these occasions, the crew elected to take a sedative, either secobarbital or chloral hydrate.

Many things were noted by this crew that had been previously experienced and described by the crew of the first visit; i.e., the change in posture, the change in the tone of the neck and shoulder muscles, and the eventual return of a normal or preflight appetite, accompanied by a slight loss of taste discrimination. The crew did not complain of a peculiar iodine or chlorine taste in the water of the Orbital Workshop or command module, but stated that the ready-to-drink beverages were much more appealing.

The food system performed its dual function of being both a life support system and an essential component of the mineral and body fluid experiments. The opinion of the crew regarding the effectiveness of the

food system is summarized by the comment of the Commander who stated that, "As long as man eats as scheduled, exercises, and gets sufficient sleep, he can stay in space indefinitely."

The only problem noted with the food system involved dispensing water soluble condiments from the containers. This form of container was extremely difficult to use because of the inability to control fluid flow in zero gravity.

Vitamin pills were provided to compensate for the thermal degradation of nutrients in the food resulting from exposure to the Orbital Workshop elevated temperatures after the launch of the Workshop. No gastrointestinal distress was reported; constipation and diarrhea were not problems. Overall comments of the crew concerning food system organoleptics were highly favorable, in spite of the fact that the crew experienced the same bland taste response as the first crew.

Much more time was afforded this crew for personal exercise, and the time was enthusiastically used. The Commander and Scientist Pilot each averaged over 3600 watts per day during their 59-day stay, while the Pilot averaged over 6400 watts per day. The crew used the bicycle ergometer, and the special Mark I, Mark II, and Mark III exercisers provided for this flight (appendix A). The Mark I unit is a floor-mounted unit with a rope and handle. The rope is wound on a variable clutch and spool mechanism with a spring return. The unit can be used in zero-g much as a floor-mounted pulley could be used in one-g and provides an isokinetic type of exercise. The Mark II exerciser is basically two handles between which one to five springs can be attached. These springs can be stretched across the chest, or behind the back, or one handle can be secured beneath the foot, enabling the hands and arms to perform barbell- or dumbell-type exercises. The Mark III exerciser is the basic unit used on earlier Apollo flights. The stress provided to the long bones and supporting tissues by these exercise devices perhaps prevented the appearance in this crew of the foot and leg paresthesias described by the first visit crew.

The hematology series experiments were accomplished eight times as scheduled. Using equipment from the inflight medical support system, the specific gravity of urines and determinations of hemoglobin were made following the blood sampling periods. These experiments will provide valuable information concerning body fluid losses in the study of the dehydration in zero gravity.

Illnesses other than the previously described motion sickness were limited to mild dermatologic problems. A sty, which developed on the Pilot's left upper lid on visit day 29, was treated with a combination antibiotic ointment which the Pilot obtained from the command module medical accessories kit. During the last week of the visit, the heavy use

of wet wipes and biocide wipes caused a drying and cracking of the cuticles and some callouse areas on the hands of all three crewmen. A light yellow staining of the calloused areas of the palms and fingers was also noted. About 3 days before entry, the Pilot experienced some drying of his lips and a fissure developed within the left lateral portion of the lower lip; this was treated with the combination antibiotic ointment (neosporin ophthalmic ointment).

A simple attempt at sweat sampling was initiated by the observation that even though the crew sweated profusely, the sweat dried without the expected residue. The Scientist Pilot had tasted his sweat and was surprised to find it was not salty. This is an especially interesting observation in view of the apparent changes in mineral controlling hormones and other variations in mineral balance. The crew used wipes to obtain sweat samples after exercising. These wipes were placed and sealed in a fecal bag and returned for analysis. Five samples were returned.

9.5.3 Entry and Postflight Phase

The crew of the second visit were active for approximately 15 hours prior to landing. This long workday had been preceded by about a 6-hour sleep period. The Scientist Pilot took an anti-motion-sickness capsule approximately 40 minutes prior to the service propulsion system deorbit maneuver. The Commander and Pilot took anti-motion-sickness medication approximately 5 to 10 minutes after the maneuver. Between 20 and 30 minutes after landing, the pulse rate readings of the three crewmen were 88 beats per minute for the Commander, 70 beats per minute for the Scientist Pilot, and 62 beats per minute for the Pilot. The command module hatch was opened approximately 45 minutes after landing and blood pressures readings were taken while the crew was still in the command module. For the Scientist Pilot, the readings were 120/70 recumbent, 150/90 sitting and, later, 170/95 while standing in the lower equipment bay. For the Pilot, the readings were 145/70 recumbent and 165/80 sitting. For the Commander, the readings were 145/85 recumbent and 150/80 sitting. The orthostatic countermeasure garment was inflated during these measurements; however, the garment of the Scientist Pilot did not hold pressure at 2.33 newtons per square centimeter as was planned.

All three crewmen exited the command module without assistance but, because of some unsteadiness and for reasons of safety because of the roll of the ship, the crew was supported and escorted to the seats on the elevator platform. The Scientist Pilot seemed a bit more vigorous and stable than the Commander and Pilot. The Commander seemed most noticeably dehydrated. Each crewman had inflated his orthostatic countermeasure garment prior to landing. As stated, the Scientist Pilot had difficulty maintaining pressure in his garment. The gage indicated 0.53 newton per square

centimeter when the command module hatch was opened. The garment was repressurized to 2.33 newtons per square centimeter prior to taking a blood pressure measurement, but after egress and arrival in the operational medicine laboratory of the Skylab Mobile Laboratories, the pressure reading was again 0.53 newton per square centimeter.

Following the microbiological sampling, the blood was drawn for the hematology experiments, and the isotope injections were made. The crewmen were then taken to the ship's X-ray department, with the orthostatic countermeasure garments still inflated, where X-ray film were taken to determine cardiac size. The stand test was performed on return to the Skylab mobile laboratories. The Scientist Pilot and Pilot had no difficulty completing this test, but the Commander, on the first attempt to stand for 5 minutes, developed definite presyncopal (faintness) symptoms. Following a 5-minute rest, the Commander performed a successful stand test. The crewmen were again X-rayed for cardiac size, this time without the orthostatic countermeasure garment.

All three crewmen performed both the lower body negative pressure experiment and the metabolic activity experiment without difficulty. The Pilot had a mild presyncopal episode, from which he recovered rapidly, following the third (highest) level of exercise during the metabolic activity experiment. The Pilot was given medication because of a complaint of early motion sickness, and all of the other tests were completed without difficulty. The entire landing day postflight medical protocol required 7 1/2 hours of the crew's time, resulting in a 22-1/2 hour workday.

The Pilot required another anti-motion-sickness capsule on the day after landing, and had no further difficulty after the recovery ship was secured at pier side. In spite of the Pilot's slight motion sickness on the ship, all three crewmen showed a marked decrease to motion sensitivity when tested in the rotating litter chair the second day after landing. The crewmen initially showed a decrease in postural equilibrium. The Scientist Pilot had apparently regained his ability to balance on one foot with his eyes closed by the ninth day after landing, but the Commander and Pilot were still slightly below their preflight equilibrium status.

The deconditioning, due to prolonged zero gravity, was present, but was less than had been expected. The three crewmen were back within their preflight data "envelopes" during the lower body negative pressure and metabolic activity experiments 5 days after landing.

The deep tendon reflexes of the three crewmen showed a marked increase in magnitude and sensitivity. The reflex, as measured at the Achilles tendon, showed a significant decrease in reaction time. The characteristics of the reflexes had returned to preflight levels by 5 days after landing.

A sensation of sore muscles along the margin of the sternum was a common complaint the day after landing. The crew also stated that the knee joints, while not painful, did not feel secure. They stated in various ways that the joints felt lax, or had lost some of the "padding" within the joint; however, this was in no way disabling. No flight-related major musculo-skeletal problem occurred. The Commander, prior to going to bed following the landing day examination, attempted to move a heavy suitcase and lost his balance (apparently due to the roll of the ship). The Commander experienced immediate pain in the lumbar muscles; this pain persisted and severely limited back motion. X-rays and a neurological examination did not reveal any significant findings. The Commander's opinion, as well as that of the examiner, was that an old chronic back strain had been aggravated.

Weight changes experienced by the crewmen from launch to recovery are as follows:

Crewman	Weight loss, kilograms	Body weight, percent
Commander	3.9	5.6
Scientist Pilot	3.5	5.68
Pilot	4.2	4.74

Strength testing conducted the day after landing showed some losses in the lower extremities, as expected, but to a lesser extent than that observed in the first visit crew. Changes in arm strength varied from a very slight loss to a slight gain. These findings are attributed to the additional exercise equipment and the vigorous exercising activity of the crew.

Standard clinical audiometric tests were performed on each of the crewmen on both the day of landing and 9 days after landing. An additional test was performed on the Pilot the day after landing. An analysis of the preflight and postflight audiograms indicated that the Commander demonstrated essentially no hearing threshhold changes on the day of landing. Relative to the Scientist Pilot's preflight baseline, no significant hearing changes were noted at any time. The Pilot did have a significant negative threshold shift at several frequencies in the left ear when tested on landing day. However, when retested 24 hours later, the corrected audiogram was essentially the same as that recorded in preflight tests. Of the conditions noted at the preflight testing, neither the Commander's typical aviator's high-frequency hearing loss, particularly in the left ear, nor the Pilot's very significant hearing loss

above approximately 6 kilohertz in both ears, had been aggravated in any manner as a result of the flight.

The following findings were noted during the postflight ocular examination. Intra-ocular pressure was down in all three crewmen as much as 0.06 newton per square centimeter on the day of landing. Pressure increased later, but still had not returned to the preflight levels when measured 9 days after landing. All crewmen had a reduction in binocular steroscopic acuity the first day, but the acuity returned to preflight levels by four days after landing. In one case, the left superior visual field was contracted and in the other two cases, the retinal arteries appeared to be attenuated upon examination on the day of landing. The visual field had returned to normal by 9 days after landing. Contraction of the superior visual field was also found in all of the first visit crew.

9.6 METABOLIC RATES

Metabolic data were collected during the three extravehicular activities, one intravehicular period, and nine inflight metabolic activity experiments. The metabolic activity data were obtained from monitoring the heart rates and liquid cooling garment temperatures.

No problems were reported nor were any apparent from the metabolic data. Metabolic rates obtained during this visit are shown in the following table.

Activity	Duration, hr:min	Metabolic rate, watts		
		Commander	Scientist Pilot	Pilot
First extravehicular	6:29	-	280	309
Second extravehicular	4:31	-	294	358
Third extravehicular	2:41	260	210	-
Intravehicular	1:56	152	-	-

The nine inflight metabolic activity tests were conducted 5 to 8 days apart during the visit. Physiologic response to mechanical work approached the preflight baseline ranges and remained within those ranges for the remainder of the flight. Immediately postflight, the crewmembers exhibited a significant decrement in response. The most obvious indications were elevated heart rates, increased oxygen consumption, and decreased cardiac output for the same work load. These changes were of the

same order of magnitude as observed in the first visit crew, but returned to normal much sooner. The preflight baseline range values were reached 5 days after landing.

9.7 RADIATION

Radiation dose predictions for the crewmen were made prior to the visit. The predictions were based on first visit dosimetry measurements assuming that space radiation environment was unchanged. Operational radiation measurements from personal radiation dosimeters, Van Allen Belt dosimeters, and electron-proton spectrometer were received daily to provide data to assess the crew dose. Comparison of crew dosages to the skin, eye, and blood forming organs are as follows:

Crewman	Tissue	[a]Projection (rem)	[b]Inflight (rem)	[c]Postflight (rem)
Commander	Skin	6 to 15	7.59	7.01
	Eye	4.6	5.06	5.14
	Blood forming organs	2.4	2.74	2.90
Scientist Pilot	Skin	6 to 15	9.23	9.78
	Eye	4.6	5.19	6.65
	Blood forming organs	2.4	2.76	3.75
Pilot	Skin	6 to 15	7.73	7.47
	Eye	4.6	5.19	5.89
	Blood forming organs	2.4	2.76	3.33

[a]The projection was for a 56-day mission and adjusted for 60 days.

[b]Integrated active readout through the end of the visit.

[c]Passive dosimeter readouts through the end of visit.

Each crewmember wore a personal radiation dosimeter from launch through the first 4 days of flight, during all extravehicular activities, and during entry. At all other times, the personal radiation dosimeters were placed at specific locations as follows. Commander - anti-solar scientific airlock; Scientist Pilot - experiment compartment wall; and Pilot - sleep compartment. The personal radiation dosimeters functioned well.

The radiation survey meter was used by the non-extravehicular activity crewmember during each extravehicular activity and the data are part of the operational measurements. Two unscheduled readings were recorded by the Commander during the extravehicular activity on visit day 10. A radiation survey prior to visit day 5 was not done because of the decrease in crewmen workload over that period.

A passive dosimeter was planned to be worn by each crewman throughout the visit. However, because of the discomfort associated with wearing the dosimeter, the Scientist Pilot wore a dosimeter only during extravehicular activities. During most of the remaining time, the Scientist Pilot's dosimeter was stowed in the sleep compartment. The Commander and Pilot either wore or carried their dosimeters in the hip pocket for the major portion of the visit. However, many times during the visit, these dosimeters were not on the person because they would float out of the hip pocket. In addition, two passive dosimeters remained in the film vault in drawers B and F from the time of vault activation on the first visit to the end of the second visit. All five passive dosimeters were returned. Each passive dosimeter contains lithium fluoride thermoluminescent chips, nuclear emulsions, high atomic weight particle detectors and neutron activation foils. The thermoluminescent readings of these dosimeters were:

Crewman/location	Reading, rad
Commander	3.67
Scientist Pilot	4.75
Pilot	4.21
Film vault drawer B	4.68
Film vault drawer F	3.71

9.8 TOXICOLOGY

There were no significant toxicological problems experienced. The presence of carbon monoxide was not checked because the carbon monoxide detector tubes left in the Orbital Workshop from the previous visit were considered nonfunctional.

The leakage of two heat exchanger fluids occurred during the visit. These fluids were Coolanol 15 (in the Multiple Docking Adapter) and water/glycol (in the command module). There was no toxicological problem associated with the Coolanol 15. There was a potential toxicity problem with aerosols and fumes of ethylene glycol in the command module and necessary steps were taken to clean up the ethylene glycol.

9.9 MICROBIOLOGY

Microbiologic studies covered three areas of interest; namely, the preflight and postflight crew microbiology, the crew oral microbiology, and the inflight medical microbiology.

To determine the microbial burden of the crew, samples were obtained from each crewman from the throat, feces, urine, and body (eight swabs) during the preflight and postflight periods for bacteriological, mycological, and virological analyses. The medically important bacteria isolated from specimens taken on the morning of launch and on the day of recovery are listed in table 9-I.

Preliminary analysis of the landing day microbiology samples indicates no increase in the presence of medically important bacteria, although there was some spread of previously identified microorganisms within the crew. The relatively few medically important bacteria isolated on the day of launch may be an indication of the effectiveness of the Flight Crew Health Stabilization Program.

Preliminary clinical evaluation of oral microbiology and immunology indicates that all second visit crewmen maintained high levels of oral health. The Scientist Pilot did not use toothpaste inflight and the first postflight examination revealed a significant amount of staining of all teeth. Resumption of normal postflight oral hygiene methods with toothpaste resulted in the removal of this stain. A summary of findings are as follows:

a. Elevation of cariogenic streptococci (*Streptococcus mutans*) in the Pilot and Commander upon examination at landing.

TABLE 9-I.- MEDICALLY IMPORTANT ORGANISMS ISOLATED IN LAUNCH AND LANDING DAY SAMPLES

Site	Commander		Scientist Pilot		Pilot	
	Launch day	Landing day	Launch day	Landing day	Launch day	Landing day
Scalp						*S. aureus*
Hands		*S. aureus*			*B-Streptococcus* (not group A)	*S. aureus*
Toes					*Escherichia intermedius*	
Groin					β-*Streptococcus* (not group A)	
Gargle		*Haemophilus parainfluenzae*	*H. parainfluenzae*	*H. parainfluenzae*	*H. parainfluenzae*	*Pseudomonas aeruginosa*
				S. aureus		*S. aureus*
						H. influenzae
Nasal	*Staphylococcus aureus*	*S. aureus*		*S. aureus*	*E. intermedius*	*S. aureus*
		Enterobacter aerogenes				*E. intermedius*
Fecal						*S. aureus*
Urine					β-*Streptococcus* (not group A)	

b. Elevation of enteric organisms at landing, especially in the Pilot. (*Klebsiella pneumoniae, Pseudomonas species, Enterobacter species*.)

c. Consistent presence of *Staphylococcus aureus* in saliva of Commander preflight, 1 x 10^2 colonies per milliliter. *S. Aureus* was present in the saliva of each crewman 5 days before launch in similar concentrations and in all but the Scientist Pilot at landing. *Staphylococcus aureus* was slightly increased above the 5-day preflight examination for the Commander and Pilot.

d. Protein values of saliva were lower than normal readings for this laboratory, beginning 5 days before launch and after landing. This is not a common finding and is unexplained at the present time. Salivary flow rates were slightly increased at landing.

e. In contrast with ground tests and the crew from the first visit, salivary immunologlobulin A was not increased at any time during the sampling period for this crew.

These changes indicate trends only and statistical significance has not been verified.

The inflight microbial samples of the crew, environment, and air were obtained as scheduled. Examination of the preliminary data shows a significant increase in the number of isolations made from the second visit samples when compared to first visit data (table 9-II). A significant increase was also observed in the microorganism cellular count per square centimeter of surface area in the Orbital Workshop when compared to that obtained on the first visit. *Staphylococcus aureus, Pseudomonas aeruginosa*, and beta hemolytic streptococci were isolated from second visit samples. *Staphylococcus aureus* was found in three of the fifteen inflight environmental samples and in five of the fifteen end-of-visit environmental samples. *Staphylococcus aureus* was also isolated from one of the four samples from each crewman. The isolation site of each of the three medically important organisms is shown in tables 9-III and 9-IV. Although the total area sampled is small, the individual sampling sites are distributed throughout all the areas of the Saturn Workshop. The high percentage of sites at which *S. aureus* was isolated, indicates that this organism may be present in significant numbers, particularly in the "living quarters." The characteristics of the microbial flora within the Saturn Workshop are changing; however, the final direction and magnitude of the changes are not understood at this time.

Air sample counts are shown in table 9-V. No significant increase in microorganisms were observed in the Orbital Workshop air. Both the 5- and 10-minute counts at [illegible] site were well within the count range observed in the ground te[illegible]

TABLE 9-II.- MICROORGANISMS ISOLATED FROM SATURN WORKSHOP ENVIRONMENTAL SAMPLES

Microorganism	Preflight	First visit		Second visit	
		Mid-visit	End of visit	Mid-visit	End of visit
Bacillus pantothenicus	1	0	0	0	0
Bacillus Sp.	0	0	0	2	2
Corynebacterium Sp.	0	0	0	1	0
Evans group A	0	1	0	0	0
Evans group B	0	0	0	1	0
Evans group D	2	0	0	0	0
Evans group G	0	0	0	1	0
Herella vaginicola	1	0	0	0	0
Micrococcus Sp.	0	1	0	0	0
Subgroup 1	0	0	0	3	1
Subgroup 2	0	0	1	1	2
Subgroup 3	0	0	0	0	4
Subgroup 5	0	0	0	1	1
Subgroup 7	2	0	0	0	3
Peptococcus marbillarum	0	0	1	0	0
Proprionobacterium acnes	1	3	0	2	7
Peptococcus magnum	0	0	2	0	0
Pseudomonas aeruginosa	0	0	0	1	0
Staphylococcus aureus	1	0	2	3	5
Staphylococcus epidermidis	0	1	0	0	0
Subgroup II	5	1	5	4	4
Subgroup IV	2	1	0	1	1
Subgroup V	0	1	1	2	2
Subgroup VI	0	0	1	0	1
Gamma streptococcus	0	0	0	0	1
Streptococcus mitis	0	0	0	0	2
Total isolations	15	9	12	23	35
Average concentration, organisms per square centimeter	0.15×10^2	0.25×10^2	0.98×10^1	0.9×10^3	0.17×10^4

TABLE 9-III.- MEDICALLY IMPORTANT MICROORGANISMS ISOLATED FROM ENVIRONMENTAL SITES

Area	First visit		Second visit	
	Mid visit	End of visit	Mid visit	End of visit
Multiple docking adapter environmental control branching duct	–	–	–	S
Airlock module control panel 205	–	–	S	–
Experiment compartment fairing over switch panel 630	–	–	–	S
Waste management compartment – fine filter	–	–	PS[a]	S
Waste management compartment – external waste processor drawer	–	S[b]	S	–
Waste management compartment – handrail	–	S	–	–
Wardroom – bulkhead between W760 and W763	–	–	–	S
Top food heater tray	–	–	S	S

[a]PS – *Pseudomonas Aeruginosa.*
[b]S – *Staphylococcus aureus.*

TABLE 9-IV.- MEDICALLY IMPORTANT MICROORGANISMS ISOLATED FROM CREW SITES

Site	First visit			Second visit		
	Commander	Scientist Pilot	Pilot	Commander	Scientist Pilot	Pilot
Toes	–	–	S[a](80)	–	–	S
Ear	–	–	S(52/80)	–	–	–
Throat	–	–	S(52/80) S(80) PS[b]	STR[c]	–	PS
Nose	–	–	S(52/80)	S	S	PS

[a]S – *Staphylococcus aureus*.
[b]PS – *Pseudomonas aeruginosa*.
[c]STR – beta hemolytic streptococci

TABLE 9-V.- COUNTS OF VIABLE PARTICLES IN SKYLAB AND SMEAT AIR (MICROORGANISMS PER CUBIC METER)

Area	First visit	Second visit
Experiment station (10 min)	106	67
Experiment station (5 min)	88	71
Orbital Workshop hatch (10 min)	6[illegible]	56
Orbital Workshop hatch (5 min)	191	120
Ground test range (10 min)	138 to 883	
Ground test range (5 min)	131 to 565	

10.0 PILOT'S REPORT

This section contains a discussion of the overall second visit as related by the crew of Commander Bean, Scientist Pilot Garriott, and Pilot Lousma. A final assessment of the hardware used during the Skylab mission requires consideration of inputs from all crewmen. Care must be taken to sort out those items which are individual points of view from those which represent a confined crew assessment. The thoughts, comments, recommendations and suggestions presented for this report must be weighed with the reports and comments of the crewmen from the first and last visits to permit an integrated overall assessment of the Skylab vehicle.

10.1 LAUNCH, RENDEZVOUS, AND DOCKING

10.1.1 Launch

The suiting up, spacecraft ingress, and system status checks were completed smoothly with only minor differences from the expected operations. Launch vehicle ignition noise and prelift-off vibrations were moderate and somewhat distracting. Lift-off was easy to discern and was characterized by rapid and distinct vibrations. After the first 5 to 10 seconds of flight, the ride was not unlike that of a well tuned Model A Ford moving rapidly over a rather bumpy road. The crew's opinion was that the events occurred somewhat faster than anticipated. The first stage engine shutdown and staging were nominal with second stage ignition occurring, subjectively, slightly later than experienced in the command module simulator. The second stage ride was much smoother, and the sensation of speed was about the same, subjectively, as that experienced in the simulator. Launch escape tower/boost protective cover jettison was executed on time; however, in future spacecraft, the number of automated launch-required events should be maximized and each one should have a manual backup capability. Comparison of the onboard computer readouts with cue cards was a satisfactory technique for monitoring the launch trajectory.

As the spacecraft approached orbital velocity, the g meter, rather than the lighting of the No. 1 engine light, was monitored to verify engine cutoff velocity. Automatic cutoff was verified earlier by this technique and, thus, an unnecessary manual shutdown command was prevented.

Preseparation checks went smoothly and were completed approximately 2 minutes prior to separation, which was completed on time with little sensation of acceleration forces. After turning the spacecraft around, the S-IVB stage (fig. 10-1) appeared stationary at a distance of approximately 30 to 90 meters. Determining the exact range, even this close to

Figure 10-1.- S-IVB stage after spacecraft ejection.

the S-IVB stage, was impossible because of the unfamiliarity with the exact vehicle size and the lack of any reference objects; however, maintaining the relative position of the two vehicles in the up/down and left/right planes was very simple. The attitude-hold feature of the spacecraft control system provided an exceptionally stable reference.

10.1.2 Rendezvous

The rendezvous timeline was straightforward and easily followed. Coordination with ground control was smooth and all required data were transmitted from the ground on time.

Several events occurred during the rendezvous that prevented a completely normal sequence. Prior to the first phasing maneuver, the spacecraft was not aligned along the orbit track, but was yawed about 0.5 radian to the right. No apparent reason for this misalignment, other than a possible accidental striking of the hand controller, could be found. The spacecraft was returned to the zero-yaw position immediately. Shortly thereafter, fireflys coming from the vicinity of the service module were observed through the right-hand window. After discussions with the ground, the service module reaction control system quad B was deactivated. An abbreviated troubleshooting procedure was performed over the next few minutes and the forward-firing thruster on quad B was found to have an oxidizer valve stuck in the open position. This quad was isolated for the remainder of the visit.

Immediately prior to the first phasing maneuver, a horizon check was attempted through the forward window. The horizon was not within plus or minus 0.01 radian of the proper window mark, but closer to the 0.6 radian window mark. Discussions with the ground revealed that the light/dark demarcation line was not the horizon, but the terminator. Future crews should be made aware of this similarity, and also that the onboard data should reflect both the real horizon line and the terminator line.

Since the spacecraft apparently failed to pass the horizon check because of the confusion concerning the horizon, the Scientist Pilot attempted to perform an inertial measuring unit star check using the optics. However, the optics could not be driven manually. The phasing maneuver was made on time using the previous inertial measurement unit attitude, since the inertial measurement unit had been recently aligned and agreed closely with the gyro display coupler. After the maneuver, the optics performed normally. This discrepancy was reported to the ground, and the ground later indicated that the optics were working normally. Section 7.6 contains a discussion of this discrepancy.

All rendezvous maneuvers were executed on time. The service propulsion system had a solid initial start transient each time it was fired. However, the subjective feeling was that the engine started about 1 to 1 1/2 seconds later than the ignition time.

The rendezvous was completed following the nominal timeline. All alignments were satisfactory. VHF ranging lock-on was accomplished normally and the flashing light beacon became visible in the optics about 5 1/2 hours after lift-off. The ground-computed ranges for acquisition of both the VHF and the beacon were accurate.

As a result of the quad B propellant leak, the reaction control system auto switches were repositioned to provide up and down translation during braking. The terminal phase initiation maneuver was executed normally with very small residuals. Information on the magnitude of all engine firings and the resulting residuals are contained in section 7.6 of this document.

The command module computer and the backup charts were in close agreement for the first midcourse correction. However, for the second midcourse correction, the command module computer solutions indicated 2.44 meters per second forward, 0.18 meter per second right, and 0.91 meter per second up, whereas the backup charts indicated 1.0 meter per second forward and 0.76 meter per second up. The command module computer solution was selected as the best and the maneuver was executed. The computer solution values were larger than expected. Also unexpected was the fact that the command module computer and backup chart solutions differed so greatly. Postflight investigation has shown that these widely differing solutions were not the result of an inflight procedural error, but were inherent in the integration calculations of the command module computer.

The VHF range and range-rate information displayed on the command module computer showed that the spacecraft passed the 1.85 kilometer braking gate at a nominal 9.1 meters per second. From this point until stationkeeping with the Workshop, braking was almost continuous because only the two-quad minus-X-axis thrusting capability existed. The almost continuous thrusting precluded the VHF from presenting accurate range-rate information to aid in the braking maneuver.

10.1.3 Stationkeeping and Docking

The transition from braking to stationkeeping was not easy to define. It was obvious when the relative motion between the command and service module and the Saturn Workshop had decreased to zero; however, accurate distance determination still was not possible. The best estimate of the separation distance is about 60 meters on the minus Z side of the Workshop (fig. 10-2). Because of the difficulty in accurately determining ranges

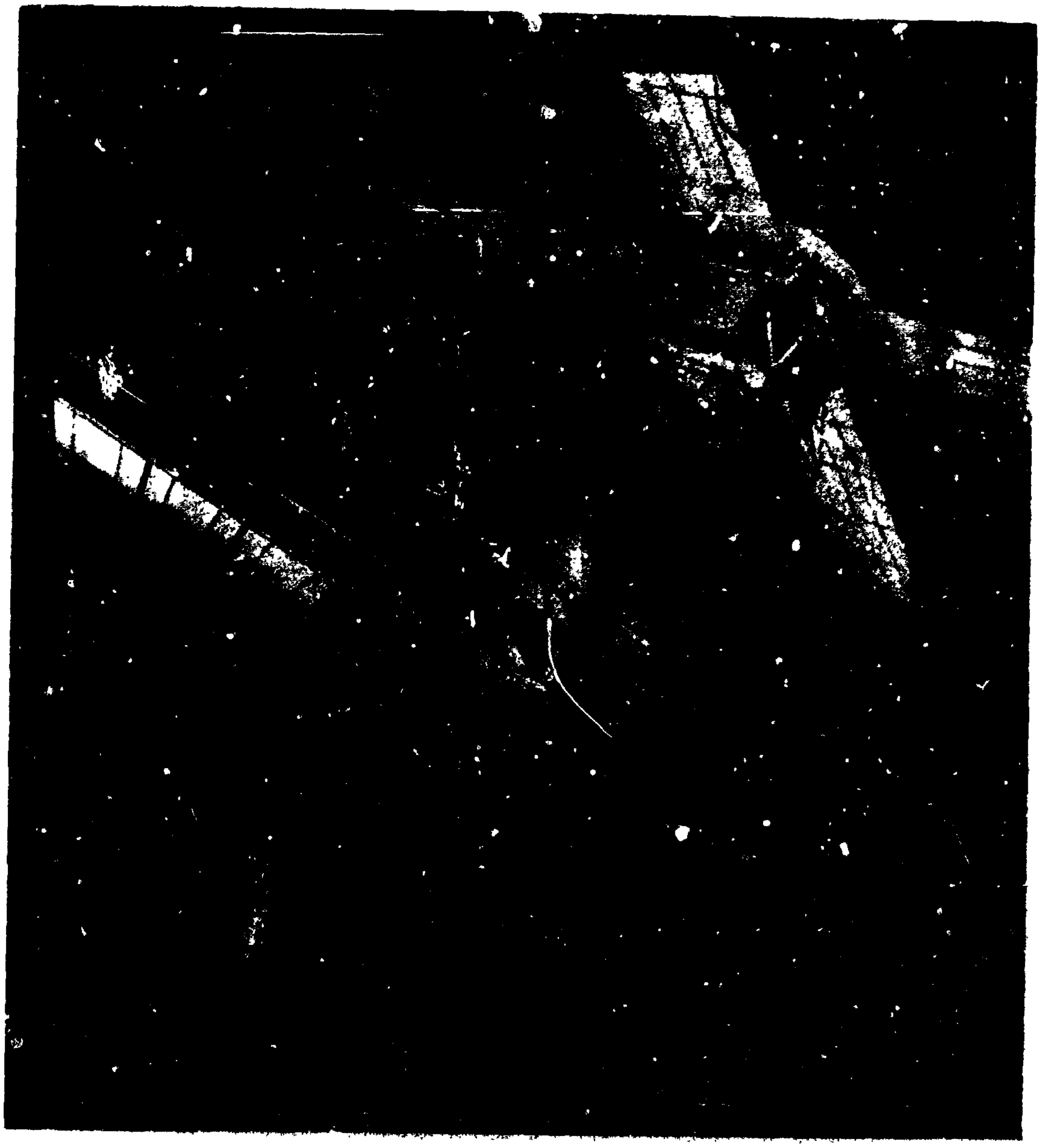


Figure 10-2.- Saturn Workshop and thermal parasol prior to docking.

by eye, the range-rate must be reduced to near zero prior to the point where it is possible to visually estimate the closing rate. The separation distance had to be reduced to less than 30 meters before left/right or up/down velocities, as well as closing or opening velocities, could be easily determined. Starting from a position near the minus Z axis scientific airlock, a flyaround inspection of the Saturn Workshop was made ending at the front of the Multiple Docking Adapter about 1 radian above the plus X axis. The television transmission became partially obscured because of a stuck color wheel during the flyaround inspection. The spacecraft was flown too near the thermal parasol which was extending from the plus Z scientific airlock. Thruster gas striking the parasol caused movement that might have resulted in parasol damage. Consequently, the command and service module was immediately flown away from the area of the parasol even though additional thruster impingement occurred during this process.

Maneuvering to the pre-docking position in front of the Multiple Docking Adapter was easily accomplished. However, to get a good line-up with the docking target, the spacecraft was positioned a little further away than had been required in the simulator. The two forwardmost Apollo Telescope Mount solar panels appeared to extend beyond the Multiple Docking Adapter further than was simulated, and it would be easy for the spacecraft to encroach upon the envelope of the two panels.

Docking velocity was estimated to be less than 0.3 meter per second at probe contact. After probe contact, plus X thrusting was performed until the capture latches locked. The required reaction control system thrusters were disabled, the command and service module was more precisely aligned in the roll and yaw axes, and the hard dock was completed. After a successful hatch integrity check, the command module tunnel hatch was removed. An inspection showed that all of the docking latches had fired. Although three of the latch locks were not fully seated against the Multiple Docking Adapter docking ring, the bungee cords were properly parallel to the X axis. The latches were allowed to remain in the configuration in which they were found.

10.2 MISSION ACTIVITIES

10.2.1 Saturn Workshop Activation

The Workshop was found to be as the previous crew had left it, with no noticeable mold or fungus and no items adrift. Generally, activation of the Workshop required more time than was planned preflight. The primary cause was motion sickness which reduced the speed with which tasks could be accomplished. In addition, some unexpected troubleshooting tasks

were performed. Several unplanned tasks were performed upon request from the ground, and some additional unplanned tasks became obvious as activation progressed. The cumulative time of the additional work lengthened the activation timeline by about 1 day. The crew's desire to remain on the timeline compromised regular eating and exercising hours and this, in turn, adversely affected the crew's overall feeling of well-being.

More tasks were planned and were accomplished than were actually necessary to make the Workshop livable on the first activation day. More time should have been set aside for the activation. Rather than planning the activation minute-by-minute, those tasks which required accomplishment in a specific order should have been identified and 3 or 4 days should have been set aside to perform the tasks. The crew could have slept in the command module, had the Workshop not been ready for occupancy. Additionally, some familiarization time should have been allotted immediately after entering the Multiple Docking Adapter to permit the crew to become acquainted with the location of various items and to acquire the necessary equipment (such as the timer, tape, triangle shoes, etc.) to begin the activation. Also, additional time should have been allotted for unplanned troubleshooting and for accomplishing other unscheduled tasks.

The following paragraphs discuss some of the problems that were experienced during activation.

Activating the water system required more time than expected because, in flushing and purging the water lines into the waste tank, the waste tank pressure would rise above the maximum permissible value. Each time the pressure was exceeded, the water dump was temporarily terminated to allow the pressure to reduce to an acceptable value. Thus, the water system purge was accomplished in a cyclic fashion, taking substantially more time than originally planned.

The food transfers were performed as planned. The command module food was eaten first and was not as palatable as the Workshop food. This probably caused the crew to feel worse than they might have, if the Workshop food had been eaten as soon as possible. The remaining command module food should have been saved until sometime later in the visit.

Many of the items in the command module stowage lockers were not unloaded during activation; instead, the items were unloaded in a piecemeal manner as they were needed throughout the visit. Thus, when returning to the command module lockers to stow something for return, items remaining there would float out, resulting in a situation where it was easy to lose items as well as difficult to stow the used items. Also, the ultimate disposition of some of the items that remained in the stowage lockers was frequently unclear. A better procedure might have been to completely unload the command module at some time during the activation phase, thus clearing the lockers for restowage on an "as desired" basis throughout the visit.

Activation of the medical equipment was also performed in a piecemeal manner and as a result, the status of the medical inventory was frequently not clear to the responsible people on the ground. This piecemeal operation resulted in the mixing of the second visit medical supplies with those from the previous visit, and also increased the general difficulty inherent in locating items required during the second visit.

The similarity of the nomenclature on the condensate system hoses caused confusion when they were used and also during troubleshooting. Attaching a diagram of the condensate system to the holding tank would have provided a helpful reference. The wetting of the condensate plates, as prescribed in the checklist, appeared to be unnecessary as the plates were still wet from the previous visit.

10.2.2 Typical Visit Day

A typical visit day began about 6 a.m. c.d.t. (1100 G.m.t.) and ended about 10 p.m. c.d.t. The crew was able to accomplish much more work during a day than anticipated preflight. This increased workload was maintained on a 7-day-a-week basis; however, several guidelines had to be observed. These guidelines were: the crew had to receive sufficient sleep (in bed on time and up on time), meals had to be eaten relatively near the planned time, and at least 1 hour of exercise per day was required for each crewman. The exercise differed between individuals. Yet, one constant factor was that the crewman had to feel that he had had a thorough workout. Adhering rather rigorously to these three requirements resulted in a high energy level and good morale. When any one of these guidelines was not followed, the crew felt the effects the next day as a lower level of alertness.

10.2.3 Scheduling Techniques

The method of generating the Skylab flight plan (by transmitting the plan via the teleprinter the evening before use) was a very effective way to schedule crew activities. Onboard planning of a day's work, either in the crewman's head or with the aid of a pre-programmed procedures computer, would not be possible because of the number of variables affecting crew scheduling. There were a large number of variables in any day's decision making. Also, the relative importance of the variables changed each day. Factors that were pertinent to planning early in the flight were not the same factors that had to be considered later in the visit, even though the same experiment activities were candidates for the schedule.

The productive work accomplished was increased by eliminating some of the smaller tasks from the flight plan such as housekeeping, out-the-window photography, and personal hygiene, and allowing them to be accomplished on a crew convenience basis. There was rarely a time when at least one of the crewmen could not break free for a 5- to 10-minute task. The crew could not completely agree on the amount of activities that could be scheduled in the flight plan nor could any other crew probably agree. Consequently, the iterative technique probably offers the only efficient solution.

The time required to perform an individual task decreases as the visit progresses. Not only is each task done more quickly, but moving from one task to another is accomplished with greater efficiency and skill. About twice as much time was required to perform a task the first or second time than was required later in the flight. Task times decreased until a stable level was reached about the 15th to 20th day of the visit.

10.2.4 Presleep and Sleep Activities

Presleep activities should begin approximately 1 hour prior to bedtime and should be maintained at a low activity level and not encroached upon by any other daily activity. Any time that meals were eaten or exercise was performed during the presleep period, the crew could not get to sleep on time, thus, contributing to decreased efficiency the next day.

Individual sleeping compartments were necessary in Skylab even with simultaneous sleep periods. As the number of crewmen increase and around-the-clock work becomes more desirable, individual sleep compartments that are light tight and soundproof become necessary.

Sleep was sound and restful in the Workshop throughout the second visit. All crewmen noticed that sleep was even more pleasant as the beta angle decreased and the Workshop temperature decreased. The sleep restraint is excellent because of the adjustable levels available, varying from no restraint at all to a rather rigid restraint not unlike that experienced on earth. The system also provided various levels of cover for warmth; however, the volume of air space, which had been designed near the foot area for easy foot motion, prevented body heat from raising the temperature of this area to provide a comfortable condition for sleeping at low cabin temperatures.

The sleep compartment airflow, entering through the floor and exiting through the ceiling, had the disadvantage of sometimes billowing the lower blankets and blocking the airflow to the crewman's head. A more desirable condition would be an airflow entering either from the side or from the top.

Throughout the flight, all three crewmen were relatively tired after a fairly hard day of work, and were ready for bed at 10 p.m. Houston time (3:00 G.m.t.). Two crewmen required about the same amount of sleep in flight as was required preflight, while the third crewman required 1 to 1 1/2 hours less sleep than he did preflight.

10.2.5 Postsleep Activities and Morning Chores

The second visit crew found that the best operational procedure was to assign postsleep activities among the three crewmen and keep them pretty much the same throughout the visit. The procedure simplified coordination and minimized references to the checklists. This policy worked well even when Earth Resources Experiment Package passes or inflight blood sampling experiment tasks were scheduled early in the workday. When experiments are conducted at the start of the workday, additional postsleep time must be provided to let the crewmen complete the items that would normally be completed after waking up. This is particularly important with regard to urine sampling because, once breakfast has been eaten, the previous day's urine bag can no longer be used.

The crew found simultaneous eating undesirable during the postsleep period because of crowding in the waste management compartment. A natural sequence developed after the first few visit days. The Scientist Pilot and the Commander weighed, then ate breakfast. Upon getting up, the Pilot, weighed, shaved and obtained a urine sample. About the time the Pilot finished changing his urine bag, the Commander would have completed breakfast and begun the morning work in the waste management compartment. When the Commander was through in the waste management compartment, the Scientist Pilot would be finishing breakfast. Often, one crewman was scheduled on the Apollo Telescope Mount just after wakeup and this further simplified the sequencing of morning activities.

The majority of postsleep activities were relatively simple and straightforward. An exception was that of weighing in the body mass measurement device (fig. 10-3), which required careful locking of both shoulder straps, rigidizing the body (particularly the stomach), and disengaging the seat release slowly and carefully. The seat release required the same deliberate technique used in squeezing the trigger of a rifle

Measuring and sampling urine was a time consuming task, but was not difficult or unpleasant. The equipment functioned as expected with a minimum of spills and messiness. The most apparent advantage in urine measuring was that each crewman determined the amount of urine voided on a daily basis, thus measuring to a degree the water intake of the previous day. This capability is desirable in future programs because of the difficulty in subjectively ascertaining whether or not a crewman has drunk adequate liquids to prevent dehydration.

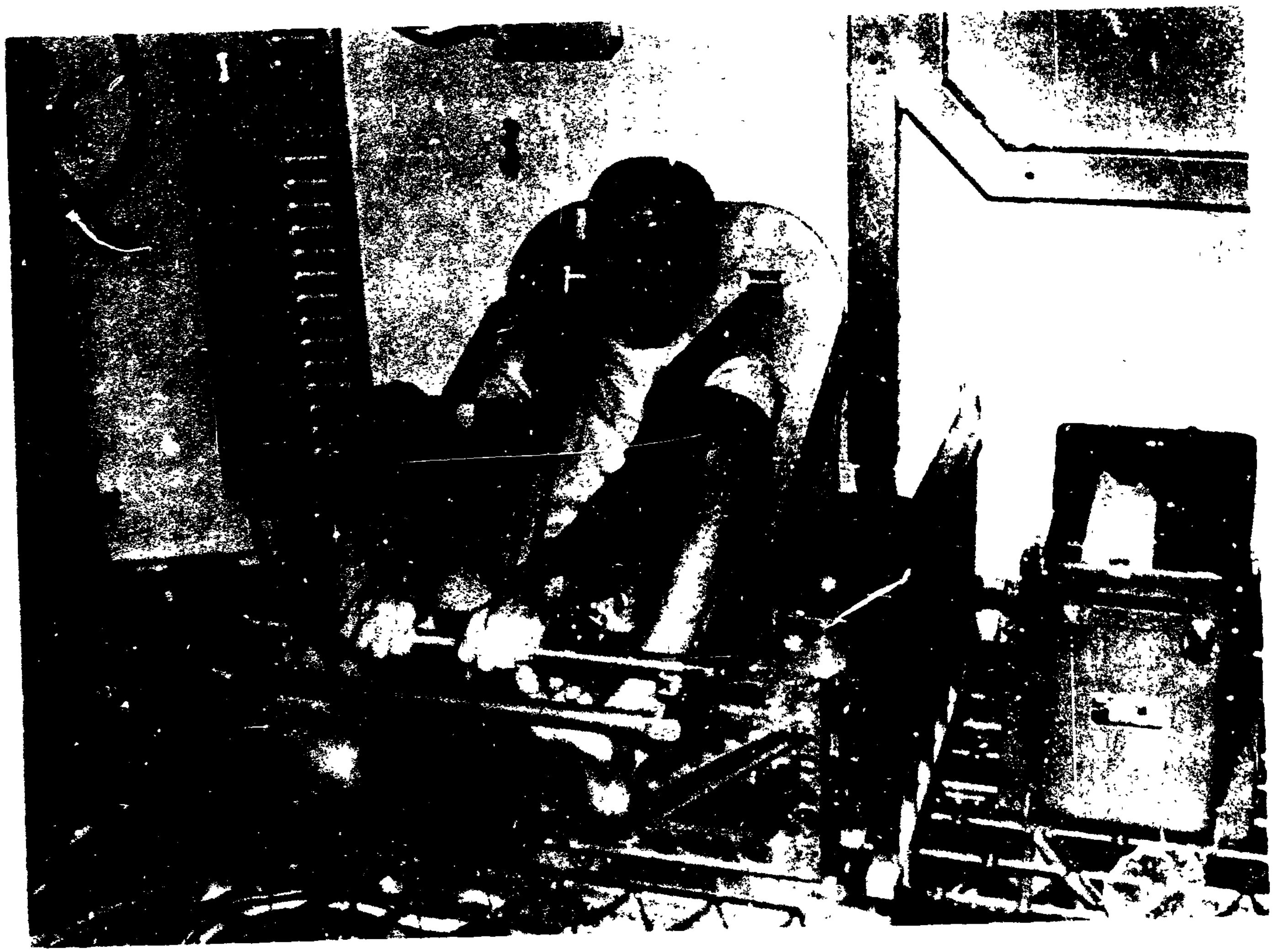


Figure 10-3.- Body mass measurement device experiment in use.

Warm water was obtained in the waste management compartment by depressing a spigot located in a stainless steel alcove. The dispenser was used for hand washing. When water was squirted on the hands, it would cling. Soap was then applied and, after washing, the soap and water mixture was wiped off with a towel. The soap was retained magnetically to the inside of the alcove, a very satisfactory design.

The waste management system was an air-entrainment system which worked very well and represented a significant improvement over the Apollo system. No significant urine spills occurred, and the two or three small ones that did occur were primarily the result of bag failures as opposed to a system failure. The fecal collector worked well, but the air suction could have been stronger. The waste management system is a credit to those who participated in the design.

The morning chores on Skylab were much the same as they are at home. Ingestible tooth paste was usually used when brushing the teeth, although the tooth paste could not be swallowed because of the medical requirements. The toothpaste was usually spit out into a tissue for disposal. Thus, an off-the-shelf toothpaste would have been better from the crew's viewpoint. The Scientist Pilot used no toothpaste at all, but found brushing with water to be adequate. Shaving was normally performed with a wind-up mechanical shaver. Although shaving could be accomplished quickly and the shaver was acceptable for use on Skylab, it did not provide a very close shave. The shaver was not capable of cutting whiskers which were more than one day old. At the end of a week, there would be several whiskers which had grown to the length that required a standard safety razor and shaving cream for removal. Shaving was closer with a safety razor, but took over twice as long as shaving with the mechanical shaver. Also, the safety razor required careful cleaning with tissue at the completion of the shave.

10.2.6 Food Preparation and Trash Disposal

The capability to prepare food (fig. 10-4), eat the food from a tray with a knife, fork, and spoon, and, following the meal, set a timer to heat the food for the next meal, was a significant factor in being able to live and work for extended periods. The addition of spices did much to improve the palatability of the food and allowed the crewman to have at least some control over taste on a day-to-day basis.

The food was stowed in chronological order by crewmen, that is, in a meal-by-meal fashion. This technique made changes to menus difficult. For future long-duration missions, the food should be stowed in a pantry-like configuration with all of the same types of food together. The pantry need not be close to the eating area, but, perhaps, in a nearby room.

Figure 10-4.- Food preparation during second visit.

This would eliminate the traffic jam that occurs in the wardroom when a crewman is trying to select food while other crewmen are attempting to prepare their food or eat. The pantry method of stowage becomes more important as the number of crewmen increases and the standardized controlled menu diminishes.

The containers were, for the most part, very well designed. The one exception was the spoon bowl packs that allowed liquid to migrate past the cutting edge, resulting in messy handling. The liquid drink containers were reliable, easy to fill and use, and were a significant improvement over the Apollo drink bags. Of the three or four drinks per day that each crewman had, there was probably only two or three that leaked during the entire mission.

The small button caps used to seal the water inlet port on some of the food containers and on all of the drink containers were superior to the folded plastic covers used on the Apollo food.

None of the spices were in satisfactory containers. The canned pepper was the best for use because the can could be squeezed, spraying pepper onto the food. Unfortunately, the pepper also tended to fly all over the compartment. The bottles were the worst because the spices just under the lid would escape when the lid was removed. The Scientist Pilot had to essentially forgo the use of spices to avoid the time it took to put them on the food. It appears that the best method of dispensing spices would be to suspend them in a liquid in some manner, and put them in a flexible bottle with a small opening similar to the plastic catsup or mustard bottles used on earth. The spice could then be squirted onto the food at close range with a minimum amount free floating in the environment.

The frozen meat was found to taste better if it was not heated as long as recommended. There were differences of opinion among the crew on whether or not the food tray heated the food sufficiently. An adjustable temperature control in future designs would allow each crewman to select the desired temperature for the food.

The Skylab food, because of the varieties available, the improved taste (frozen food in particular), and the visual appearance, was much superior to the Apollo food. The ability to have all the food in a tray at one time and sit down to an earth-like meal is much more enjoyable than handling the individual food items in plastic bags. The Skylab-type food system should be the minimum acceptable design considered for future spacecraft. The crew's ability to work day after day with high levels of energy, efficiency, and morale could be largely attributed to the exceptionally good food system.

Disposing of food waste aboard Skylab was a time consuming and an unpleasant chore. In view of the total amount of waste products that are generated, and the fact that waste must be handled more carefully in the zero-g environment, design of the waste disposal system should have particular attention. Stowing used food cans and containers in larger cans and then moving the larger cans at least once a day to disposal bags wasted a lot of time and was very messy. In the future, the design should be such that the waste need be handled only once. Some sort of simple compacter may be the answer to this problem.

Trash disposal was accomplished by placing all disposable items in bags and putting the bags into a single trash airlock. The bags could not be filled too full or the airlock mechanism could be jammed during the final disposal operation. The lid on the trash airlock was difficult to close and usually required a second person to stand on the lid and push down so that the lid could be locked without additional bending of the interlock push rod on the locking handle. The trash airlock received careful treatment because the amount of trash collected during the visit could not have been stowed elsewhere within the Workshop without impacting operations.

The trash airlock worked satisfactorily; however, the trash airlock was a single-point failure item that, if it had failed, would have changed the waste disposal task from an unpleasant situation to an almost impossible one. Future space station designs should provide redundancy in the trash disposal system or be designed such that any jam could be repaired by the crewmen.

10.2.7 Housekeeping

Housekeeping on this visit included a number of tasks such as disposing of trash, vacuuming air inlet screens, cleaning various areas, applying biocide, and replacing filters and other time-limited items. In addition, a host of systems checks, tests, and configuration tasks were included under housekeeping for lack of a better classification. These tasks were typically scheduled by the ground on the basis of prearranged intervals such as 2, 3, 7, 14, or 28 days, as required.

Vacuuming of the Orbital Workshop mixing chamber screen, the waste management compartment screen, and other environmental control system screens was performed on an as-needed basis, usually about every other day. Screens with large mesh did not require vacuuming since most of the debris passed through them. The fine mesh screens however, collected a great deal of debris such as lint, food particles, hair, and paint chips. The debris was easily removed with the vacuum cleaner. Future designs should insure that fine mesh screens are well exposed for easy cleaning.

A large amount of dust collected on the Orbital Workshop heat exchanger plates because coarse protective screens were used rather than fine screens. The dust affected the heat exchanger performance.

Cleaning of various items and applying biocide were tasks scheduled by the ground. Requests were made to clean many items with water. In other cases, requests were made to clean items with biocide wipes, which were iodine-impregnated cloth pads. The messiest area in the Workshop was the garbage collection area where used food cans and plastic bags were placed after each meal. At the end of the day, this area would begin to smell bad, and the garbage area was cleaned daily and wiped with biocide wipes every third day.

There were a number of systems checks which were also scheduled by the ground, particularly the caution and warning system. These were scheduled too frequently, and a better procedure would have been to check these systems no more than once per month.

In general, housekeeping activities such as vacuuming of the screens, cleaning, applying biocide, and performing some time-limited item replacements were scheduled more frequently then necessary. As the visit progressed, the time for performing these tasks was obvious to the crew and, thus, it was unnecessary for the specific tasks to continue being scheduled.

During the early design stages a great deal of concern was expressed about free water droplets and splashes, and the release of particles into the atmosphere of the Workshop. In actuality, water droplets simply cling to the walls and evaporate rapidly in the dry atmosphere. Particles collect on the fine screens and can be vacuumed off readily. As the visit progressed, it became obvious that it was not necessary to take special precautions to prevent debris from being released.

10.2.8 Onboard Maintenance

Two major onboard maintenance tasks that had been preplanned were executed during an extravehicular activity: the erection of a twin-pole sunshade and the connection of a rate gyro six-pack. A number of other smaller tasks for which no preflight training had been given were also successfully performed during extravehicular activity. Flight results show that any task that could be reasonably performed in the underwater training facility could also be performed during extravehicular activity.

Several maintenance tasks were accomplished inside the Workshop during the visit. These included the disassembly, inspection, and replacement of the Airlock Module tape recorders, replacement and electrical continuity tests of the heated water dump probe, replacement of the video

tape recorder and the removal of several cards from inside the recorder, tightening of the chain linkage on the experiment S019 articulated mirror system, repair of an ergometer pedal, and electrical continuity tests of cables which were exhibiting an intermittent condition.

The tools used to perform these maintenance tasks were, for the most part, satisfactory for accomplishing the task; however, some of the specialized tools did not work as well as standard off-the-shelf tools. For example, the socket-type tools fit very loosely. Some of the maintenance tasks were not foreseen and, thus, specialized tools were not available. In these instances, either an available tool was used or a tool was improvised to solve the problem. Not only should specialized tools be supplied in future designs, but standard tools such as one might have on his home tool bench should also be provided. This visit showed that, in general, given the proper tools, any maintenance task that can be performed on the ground can also be performed in space. In performing maintenance tasks in zero-g, a method for containing and retaining tools and removed parts must be provided. A solution would be a central work bench area where the various components could be taken for maintenance, with tool and component retention capability and good lighting.

10.2.9 Clothing and Footwear

Used clothing items were discarded when soiled, since no onboard laundry facilities existed. Enough clothing was provided to change socks, T-shirts, and shorts approximately every other day. The crew preference would have been to provide enough clean socks and shorts to change each day. The brown durette turtleneck shirts were not used because they did not absorb perspiration well, and they fitted more tightly, and were warmer than the white T-shirts.

Trousers were provided on the basis of approximately one change per week, and this was more than adequate. The trousers had three pouch-type pockets and one flush pocket. The pouch-type pockets were used mostly because they could contain more items. The flap on the scissors pocket in the trousers was so short that the scissors were continually being knocked out and lost.

The quantity of long-sleeved jackets supplied permitted a change rate of about one every other week, but one jacket for every four weeks would probably have been sufficient. The loops, snaps, and holes provided for communications equipment were seldom used.

The two-piece trouser and jacket concept was preferable to the one-piece flight suit concept because a variety of alternatives was provided, each of which was used at one time or another. The jackets and trousers had elastic cuffs at the wrists and ankles, so that the sleeves and trouser

legs would not ride up on the body in zero-g. This visit showed that elastic cuffs are unnecessary, as the clothing did not ride up when the cuffs were removed to provide better ventilation. Whether the snaps for connecting the trousers with the jacket were used or not used seemed to make no difference. However, the snaps on the back of the clothing made an uncomfortable pressure point on the spine during entry and should have been removed.

Two types of footwear were provided: soft boots, much like house slippers, and triangle shoes. The boots were seldom or never used, and the triangle shoes were used almost exclusively. The triangle shoes were made of heavy canvas and had a toe cap which prevented fraying and excessive wear. Each shoe developed a pair of holes above the heel as a result of an insert which wore through from the inside. One boot developed a 10-centimeter tear parallel to the sole from loads exerted while pedaling the ergometer. Overall, the triangle shoes were comfortable and the better of the two designs.

10.3 COMMAND AND SERVICE MODULE SYSTEMS

The command and service module systems performed satisfactorily with the exception of the problems with the reaction control system quads B and D discussed in section 7.7 and the coolant leak discussed in section 7.8.

The fundamental lesson relearned from this flight is the need to communicate information about unusual systems behavior as soon as the condition is noted by either the crew or ground personnel. Examples of this were: fireflys visible out of the right-hand window that were manifestations of the quad B oxidizer leak; fireflys seen from the Orbital Workshop wardroom window followed by a rapid temperature drop in quad D that turned out to be an oxidizer leak; and the discovery by ground personnel that the primary cooling system accumulator was losing fluid and the condition showing up later as a glob of liquid behind a command module panel. The unusual response of the optics to manual drive commands was also an example where rapid coordination between the ground and crew resulted in a quick solution to a problem.

The 7-day command and service module system checks were extremely important not only from the point of view of exercising dormant spacecraft systems and components, but for periodically inspecting the spacecraft for condensation and leaks. This visit showed that fluid leaks are not as apparent in zero-g as they are in one-g in that the fluid does not tend to collect at the lowest point. Instead, it spreads out rather uniformly along surfaces near the leak, and thus, does not always catch the observer's eye.

An unexpected behavior was the growling noise emitted by the gimbal motors on the entry minus 5 day check. The noise was present during all gimbal motor checks. At the time, the growling was attributed to normal gimbal motor operation and, in a fully powered up command module, the noise would be obscured by the operation of pumps and fans. This proved true as no unusual noises were audible during entry.

The VHF private communication loop did not perform in a consistent manner. The communications would be excellent through one Spaceflight Tracking and Data Network site and at the next site, without touching the onboard switch configuration, no two-way communications would exist. This unsatisfactory behavior became more frequent near the middle of the visit. However, various changes were made in ground procedures and the condition improved during the final weeks of the visit. Section 13.2 discusses this problem in more detail.

The fuel cells performed perfectly. However, while verifying the spacecraft configuration prior to entry, several circuit breakers were found that were not configured in accordance with the checklist. The systems checklist for fuel cell shutdown apparently does not require repositioning of these switches in the quiescent configuration. The fitting used to dump the command and service module waste tank into the holding tank in the Orbital Workshop prior to fuel cell shutdown was not removed at the conclusion of the dump, but remained in place until the entry quiescent mode checklist verification was performed. The oxygen vent valve and pressure relief valve were also not scheduled for removal after completing their usefulness, but were still in place during the entry quiescent check. All of these fittings, switches, and circuit breakers should be scheduled for removal or repositioning as soon as they have served their usefulness so that the command and service module is in the best possible entry configuration in the event of rapid undocking and entry.

While reinstalling the center couch on entry day, the lower frame could not be raised sufficiently to align the lower and upper frame. A screw in each side of the couch shoulder break point was found partially unscrewed, preventing the two faces at the shoulder joint from aligning properly. The screws were tightened, allowing the couch frame to be aligned and pinned.

10.4 SATURN WORKSHOP SYSTEMS OPERATIONS

The basic concept of ground control of the Workshop systems with an onboard monitoring capability was a good one. The caution and warning system alerted the crewmen to time-critical systems problems, and those which were not time-critical could best be handled by the ground anyway.

This permitted the crewmen to maximize their time with the experiments. Occasionally, the ground asked the crewmen to perform such tasks as adjusting a potentiometer, throwing a switch, or changing a valve. These were accomplished very simply and seldom interfered with other tasks.

10.4.1 Caution and Warning Systems

The caution and warning systems performed normally. Typically, all crewmen would answer a caution and warning signal at night, but during the work day, only the man closest to the caution and warning panel would answer the alert. Several caution and warning parameters, such as molecular sieve flow and Orbital Workshop interchange duct flow, were not as time-critical as orginally believed during the early design phases. When these alarms caused a nuisance, the caution and warning system was inhibited and the ground alerted the crew to problems arising in other systems. Inhibiting the non-time-critical caution and warning parameters caused no problems.

10.4.2 Communications

Although the spacecraft was very quiet, sound did not propagate as well at 3.45 newtons per square centimeter as it does on earth at 10.14 newtons per square centimeter. As a result, the communication stations were set at a relatively high volume to be heard throughout the living area. All crewman had to listen to all communications between the spacecraft and the ground so that they were kept abreast of the visit activities. When the communication stations were adjusted so that at least one station could be heard in all parts of the spacecraft, the communication stations would interfere with one another when transmitting, causing a loud squeal onboard and on the ground. The noise was unacceptable. The communication boxes in the Orbital Workshop dome and the one at the experiment M512 work station were never used.

After the third extravehicular activity, a higher-than-usual volume was required on the intercommunication system to hear adequately. However, after increasing the volume, a motor-boating sound was heard on one of the channels. A ground-requested circuit breaker reconfiguration appeared to solve the problem. However, the motor-boating sound reappeared in the command module after the command module and the Saturn Workshop communications umbilicals were disconnected on entry day. Thus, the problem was in the command module systems and is unsolved. Section 17.1.10 contains a discussion of this problem.

10.4.3 Teleprinter

The teleprinter was an excellent device and much more information was received from this device than could have ever been received by voice communications alone. Since the ground could operate the teleprinter anytime the spacecraft was over a station, information could be sent whether the crew was awake or asleep without tying up one of the crewmen to receive the communications. A minor problem was corrected when the black drive roller came off the shaft of one teleprinter head and had to be replaced.

10.4.4 Television

The onboard video system had two operational shortcomings. One was that the video tape recorder power switch was located on the recorder in the Multiple Docking Adapter. When recording television, a crewman had to float to the Multiple Docking Adapter, turn the recorder on, and then float back to wherever the television picture was to be taken. When the television transmission was completed, a crewman again had to float back and turn the power off. In a scene which required many different camera positions or many short intermittent scenes to be taken, numerous trips back and forth to the Multiple Docking Adapter proved troublesome and time wasting. The second drawback was that no means existed to tell the video signal was being routed to the tape recorder or was being blocked by an improperly configured switch. A "record" switch that could power the recorder and a green light that would illuminate only when the signal was actually being recorded would have saved considerable time.

10.4.5 Tape Recorders

Several tape recorders were replaced and the task was very simple. All tape recorder malfunctions resulted from belt problems. The drive belt broke in two of the recorders and the tape pinch belt came off in the tape drive system of the third recorder. All failures appeared to be repairable had new belts been available.

The major problem with tape recorder operation occurred because the ground was unable to determine when the voice recorder was being used. The recorders were frequently dumped while in use and the person using the recorder at that time did not realize a dump was in progress. Thus, information was occasionally not recorded when thought to be, and the recording had to be repeated. The ground always notified the crew when a tape recorder dump was to be made but, usually, the crewman using the tape recorder could not or did not hear the ground call because he was using the "record" channel and was not monitoring the uplink voice channel.

10.4.6 Environmental Control Systems

The Orbital Workshop primary coolant loop failed because of a leak, but the secondary coolant system performed satisfactorily. The availability of only one coolant loop, however, required a change for the third extravehicular activity in that air cooling was used for the suits rather than water cooling.

Several coolant panels were removed while searching for leaks in the primary coolant system. However, the panels were not designed to be removed in flight and, therefore, were very difficult to remove because of the high torque loads on the bolts which held the panels in place. Easily removed panels should be used on future spacecraft.

The temperature in the Orbital Workshop was usually quite comfortable. It was a few degrees cooler in the Multiple Docking Adapter and in the command module than it was in the Orbital Workshop. The temperature in the Orbital Workshop decreased a few degrees when the twin-pole sunshade was deployed. The temperature change with beta angle was also quite noticeable, being a few degrees cooler and more comfortable at beta angles near zero. The temperature in the Scientist Pilot's sleeping compartment was a little higher than that in the other sleeping compartments, particularly after Z-axis local vertical maneuvers. The temperature was also a little higher behind the experiments M509/T020 area than it was in other Orbital Workshop areas or on the rest of the Orbital Workshop walls.

10.5 VISUAL OBSERVATIONS AND UNUSUAL EVENTS

Several events worth recording occurred during the visit. On one occasion, an unusual event was observed on the experiment S052 television screen on the Apollo Telescope Mount. Periodically, spherical objects were noticed drifting past the occulting disk, and the objects frequently had what appeared to be a "black hole" in the center that looked like a washer.

About 10 days before entry, a rather bright reddish object that looked like a satellite was observed from the wardroom window. Upon closer examination, the object appeared to be brighter than Jupiter and had a very definite reddish hue, although the incident sunlight was well above the earth's horizon. The object was observed for about 10 minutes prior to sunset. Its position changed very little in the wardroom window; at the most, the angular change was 0.17 to 0.35 radian over the 10-minute observation period. As the Workshop went into darkness, the crew noted that there was a 5- to 10-second delay before the object's reflected light was also extinguished. The object's color definitely changed to a

more reddish hue during about the last 20 seconds of visibility. Based on the 5- to 10-second delay in disappearance, the object's location was, perhaps, 55 to 90 kilometers from the Workshop. A variation in brightness of, perhaps, plus or minus 30 percent with a 10-second peak to-peak period was also noted, leading the crew to believe that the object was rotating. This particular object was not observed again.

On two occasions, a "blizzard" of small particles was observed. These particles were the effect of the failures in the two reaction control system quads. The first was observed from the command module and the second was observed on the morning of visit day 6 through the wardroom window. The event was a very heavy shower of bright particles streaming ing by the window and was readily identified as spacecraft venting.

Following periods of activity on the sun, several bright aurora were observed from the structural transition section windows. On one occasion, about visit day 45, a bright aurora was observed near the southern auroral zone on each succeeding orbit for 5 or 6 orbits.

A number of sounds were heard in the Workshop that were worth reporting. Some of these sounds were due to thermal effects on the structure, and were heard primarily before going to sleep because this was the quietest time in the vehicle. One sound, which lasted for about 4 or 5 seconds, produced a rumbling noise like rolling thunder. Thruster attitude control system firings were very audible and sounded as if someone were pounding on water pipes in a basement. A white plume, which was visible outside the spacecraft, was produced at the same time. The sound of ground-commanded dumping of oxygen into the Workshop was also very noticeable as an intermittent, loud, hissing noise in the structural transition section area. When the nitrogen gas was released from the molecular sieve valve actuators every 15 minutes, a clank and a momentary hissing noise were also audible. The sound of a continuous, hissing leak was present when the suit drying blower was in operation. The refrigeration pump made a continuous high pitched whine, but the sound was not loud or objectionable and was masked by other noises. The failure of Apollo Telescope Mount coolant pump A was heard in the Airlock Module and sounded like an automobile water pump which was about to fail. The sound was also described as being like air escaping under water. The liquid cooling garment water pumps also made a rather harsh sound which varied in intensity with no apparent regularity when the pumps were operating.

10.6 FLIGHT DATA FILE

The command and service module onboard data files were excellent, complete in content, and simple to read. The teleprinter format that was used to update changes during the flight was, at first, difficult and time consuming to use when incorporating changes because, in many cases, pen and ink changes had to be made. Later, this approach was modified to make whole sections replaceable or to be taped in place. This technique was superior because incorporating changes into the checklists was not only faster and easier, but the changes were more readible when actually executing a maneuver or performing an experiment. The teleprinter pad change must be sized properly to insure that the change will fit in the space available in the checklist.

The plastic tubing that was shrunk over the large metal rings that held individual checklists together served no positive retention purpose and inhibited page replacement. The tubing was removed to facilitate page changes and no accidental opening of the metal rings occurred.

The Saturn Workshop flight data file was an improvement over that of the first Skylab visit, primarily because of the extensive use of cue cards rather than checklist books for experiments that were conducted on a repetitive basis. The cards were easier to read and were instrumental in saving considerable crew time.

The transparent tape and tape dispenser were inferior to products which are commercially available. The tape was difficult to tear and the dispenser's serated edge was unusually coarse toothed, further contributing to the difficulty in tearing.

A considerable amount of time was expended incorporating checklist changes and updates. The number of these changes probably could not be reduced, but the time required to incorporate each change could be reduced if some sort of desk were available. A food tray top was used as a temporary desk. A spring with attached clips stretched across the food tray top and magnetic card holders from the entertainment kit were used to restrain teleprinter checklist changes. Scissors, tape, and a pen were stuck anywhere that could be found. This system was not completely satisfactory, but was better than nothing. A more complete desk to facilitate onboard paperwork should be provided on future vehicles. The desk might even double as a workbench.

Flight data file configuration control was good, with the possible exception of some Apollo Telescope Mount changes. Almost any changes that were first discussed over the communication loop resulted in an uplinked teleprinter change to the checklist the next day, except in the

case of Apollo Telescope Mount operations where many improvements and modifications discussed and agreed upon were never sent up officially. Some confusion was created in flight because all members of the crew were not always aware of all conversations. In the future, official teleprinter checklist changes should be transmitted as soon after the change as possible. (Editor's note: The mission control personnel in charge of updating the crew's flight data file are aware of and, have resolved this problem by implementing changes as soon as possible after air-to-ground discussions with the crew.) The format should be standardized to facilitate understanding and incorporation.

The Earth Resources Experiment Package site books were well designed. The large-scale charts and photographs were the most useful for locating the sites because only the major surface details were visible, just as the major surface features were the only ones visible from orbit at acquisition. The closeup pictures and small-scale charts were excellent aids in determining precisely where to point the camera at maximum zoom. The best large-scale charts and pictures should be included in the Earth Resources Experiment books.

The two orbital maps provided a simple means for determining the position of the Saturn Workshop over the earth's surface. Unfortunately, the maps did not provide a sufficient amount of detail to locate more than the most general sites for photography. The book of smaller scale aircraft-type world maps placed onboard for this visit was a great help in correcting this deficiency, but more improvements are still required. The maps were not designed specifically for orbital use. Consequently, the features visible from space were not duplicated and this was, of course, often confusing when searching for small specific points of interest. Some consideration should be given to devising special charts and maps for future space flights that show the primary features that are visible from a specific orbital altitude.

The flight plan book was useful in that it served as one point where all permanent messages were kept for future use. A listing of the current problems was also kept in the book and was a useful reference as it allowed the crew to stay abreast of the status of spacecraft systems. This listing also reflected the ground analysis and status of each problem, i.e., whether corrective action was in progress or a problem had been classed as a permanent failure. The reports kept other crewmen informed and obviated a lot of discussion with the ground. The day/night station passage sections of the book were not used and should be eliminated as well as the South Atlantic Anomaly times, which did not prove useful.

One device that was particularly helpful for handling onboard data, was a 30-centimeter-long string with a snap hook at one end and a metal ring at the other. One end of the string was attached to the checklist

and the other end to the crewman's garment. A rubber band was used to keep the book open to the correct page, and this allowed the crewman to have both hands free to perform a function. When a function was complete, the checklist could be retrieved easily and checked for the next step. The only disadvantage to the string and rubber band scheme was that the book sometimes caught on lockers or hatches as the crewman was floating past and the pages were pulled out or the holes were torn open. The small knee board is not acceptable because the checklist pulls free even more easily. A better system is required that will keep the checklist at hand and open to the proper place and leave both hands free for other work.

10.7 SATURN WORKSHOP HABITABILITY

The following paragraphs present the observations concerning living and working in the Skylab cluster. Additional information on the habitability of the cluster is contained in section 4.0 of this report.

10.7.1 General Arrangement

The normal one-g type compartments with the wall perpendicular to the floor, such as in the Orbital Workshop, were superior to the rather random cylindrical orientations of the equipment in the Multiple Docking Adapter. The one-g arrangement was preferable in training because it allowed an individual to work in a one-g field in the same manner as he would work in zero-g. But even in zero-g, a crewman tended to think in terms of the same up-and-down and orthogonal references as on earth.

A person had to be well restrained and have his hands free to perform useful work. The triangular grid floor design and the one-g equipment arrangement allowed a crewman with triangle shoes to assume a natural position relative to either a planned or unanticipated work site. However, with the random orientation of the Multiple Docking Adapter, securing oneself for work was different at each site and some convenient box, handle, or protuberance was not always available to wrap one's legs around.

The crewmen found that small living spaces such as the Multiple Docking Adapter were rather crowded when more than one person was present. The waste compartment and the airlock compartment are also good examples.

The sleep compartments were, for the most part, adequate in size because, generally, only one person was using them. However, any future space vehicle using staggered sleep cycles should have compartments that are light tight and more sound proof than the Skylab installation.

The airlock compartment had several design deficiences. When the compartment was being used as an airlock for extravehicular activity, it was relatively crowded and there were no good stowage restraints for either the equipment that was going to be used during the extravehicular activity or for the experiments retrieved during the extravehicular activity. These items could only be secured with tethers as no specific provisions existed for restraining the items outside of the crew operating envelope. Airlocks in future designs should provide good crew foot restraints, and good stowage restraints for the pre- and post-extravehicular-activity requirements.

A great number of power cables, television cables, tape recorder cables, light cables, and fan cables were randomly routed throughout the Workshop during normal day-to-day operations. No convenient way probably exists to install permanent connection points where different devices may be used; however, some improvement to the present unwieldly scheme needs to be devised in future applications.

10.7.2 Lighting

The lighting throughout the living areas was too dim to support precise maintenance tasks or extended periods of reading. A brighter light level is needed. Lighting was also, in some areas, misplaced. For example, all of the lighting in the waste compartment was overhead, thus, casting shadows under the chin and on the neck. This made shaving and cleanup after shaving difficult.

10.7.3 Temperature

After the twin-pole sunshade was erected, the cabin temperature stayed at a very comfortable 293° to 297° K. Most of the crewmen preferred the temperature in the 293° to 294° K range. The adjustable vents worked well, although the vents generally did not require adjustment. Airflow in all the compartments was satisfactory. A separate temperature control in the waste management compartment would have allowed the crew to be more comfortable when taking sponge baths and is recommended for future vehicles.

The humidity within the workshop was entirely too low. The crewmen had dry noses, hands, lips, cuticles, and ends of fingers, and at least one crewman had periodic nosebleeds throughout the visit.

10.7.4 Restraints

As discussed in paragraph 10.7.1, the feet must be restrained to perform useful work. The triangle shoes interfaced well with the grid structure throughout the Orbital Workshop, under the Apollo Telescope Mount panel, in front of Earth Resources Experiment Package panel, and around the dome lockers. The triangle shoes were worn all day and consistently provided the best restraint when performing any task. A system such as this is mandatory for future vehicles. The waste management compartment was designed without triangular gridwork to facilitate spill cleanup. However, the crew believed that this was an unneeded precaution and operations within that compartment would certainly have been improved had the compartment been constructed like all of the others.

The handholds were placed throughout the spacecraft in the places that were believed to be the most appropriate during preflight tests. The selection logic was faulty in that handholds had been visualized at most work sites, whereas natural handhold points such as small boxes, airlocks, and door handles were frequently sufficient at these places. Handholds should have been placed where changes in direction of travel were required, such as near hatch openings. Some temporary handholds were placed at the direction change points, but these simple elliptical-cross-section handholds were not large enough to allow adequate wrist leverage to change the crewman's direction. Neither natural handholds nor those designed for specific purposes were adequate substitutes for a foot restraint when working. The fact that crewmen do not move around hand-over-hand but, rather, push off and soar from point to point, will aid in establishing handholds for future designs.

The rigid fireman's pole was more useful than the non-rigid fireman's strap in that the rigid design provided a torquing point for rotating the body, and the crewman could push off sideways in any direction anywhere along the pole. However, both of these translation aids proved unnecessary because of the relative ease with which one could move by merely pushing off and floating to the desired destination. The rigid pole was removed for most of the visit and was more of a hinderance than an aid after reinstallation during the deactivation phase.

10.7.5 Stowage

The stowage provisions throughout the Orbital Workshop were generally good; however, the advantages of having all like items together should be emphasized. The majority of time spent retrieving a needed item was not spent in going from a work station to the stowage location and back to the work station. Rather, it was spent in trying to remember where the required item was stowed. A significant time saving could be realized by simplifying the stowage for ease of memory rather than stowing the items for relative closeness.

The metal walls and lockers were exceptionally rugged, as was the paint covering them. This proved beneficial because the triangle shoes were often contacting the walls, ceilings, and stowage boxes, and without the relatively tough construction and materials, structure might have broken or paint might have chipped. Thus, the utility and appearance of the Workshop would have been degraded. The 30-centimeter-long springs that could be attached to the front of the lockers were one of the best means for temporarily securing items. Sufficient springs were aboard to perform most tasks; however, springs should have been permanently installed on all locker doors and boxes. Spare springs, with appropriate mounting provisions, would still be necessary for use at locations not foreseen prior to the flight.

The short and long snap straps were good devices. In fact, had the short snap strap been about 7 to 8 centimeters longer, this one strap would have fulfilled the needs of both sizes of straps. For the longer equipment restraints, which were provided to handle larger packages with attendant larger strap loads, it would have been desirable to use lift-a-dot snaps that were oriented to withstand additional tension without releasing.

In flight, the cameras were seldomly placed in the stowage locations because time was saved when the cameras were left in their use positions. In many cases, a restraint was not provided at such a location, and a makeshift restraint was devised. Better restraints for the hand-held cameras near the wardroom window or the structural transition section windows would have improved the operations.

Little or no difficulty was experienced with the wide variety of latches and fasteners used in flight. Lids and doors to cabinets could have had temporary metal straps or pip pins to handle launch loads and, once the spacecraft is in orbit, the pip pins or straps could be discarded. In zero-g, magnetic latches or simple friction could have been relied on to retain lids.

Velcro was a most useful restraint. All the places where Velcro will be needed will not be thought of prior to flight. Therefore, a good quantity of precut 2.5-centimeter squares of male and female Velcro should be available for crew installation.

A strong glue was needed on several occasions to solve specific problems. For example, there were not sufficient restraints in the chiller. An attempt was made to attach some sticky-back snaps to serve as temporary restraints; however, this was not possible with the moisture and the cold.

The standard snap pattern which interfaced with temporary stowage bags, trash bags, etc., was used frequently.

10.7.6 Personal Hygiene

Although the water dispenser in the waste management compartment was usable if one was careful, the lack of a suitable facility for washing the hands and face was a significant shortcoming. The hand soap was pleasant to use and the metallic insert used to hold the bar to the side of the hand washer compartment magnets was clever. The squeezer, used for removing excess water from cloths, would squeeze the washcloths satisfactorily, but was not large enough for towels. Also, the seals around the compression piston of the squeezer leaked frequently and squirted water around the compartment.

The shower was used only three times because of the time required to prepare for the shower and the cleanup afterwards (fig. 10-5). Also, a person was cold when actually taking the shower. The suction squeegee in the shower was too rigid and did not conform to the body, thus making it difficult to remove water from the body. Most of the water had to be removed with towels after the shower. The preferred method for bodily cleanliness was to wash nightly with a cloth, soap, and water because it was easier and quicker. The shower soap was not popular with the crewmen as it had a strong odor and slight residue, both of which would cling to the body for several days.

10.8 MEDICAL EXPERIMENTS

A number of medical experiments were conducted during and after the second visit. The results of these are discussed in subsection 4.2. Some of the significant observations and analyses by the crew are presented in this subsection.

10.8.1 Experiments M071/M073 - Mineral Balance/Bioassay of Body Fluids

Greater variation should be permitted in an individual's mineral, protein, and caloric levels, thereby enabling a diet selection from the full range of foods. The crew believes that greater variability in the food might have made the meals more palatable, and possibly could be important in earlier stabilization of the crewmen's weight. Minimum mineral intake requirements could still be met.

More extensive tests of the palatability of each food item for the individual crewman should have been made. The tests that were made came too late in the menu planning cycle and were too few in number. Many of

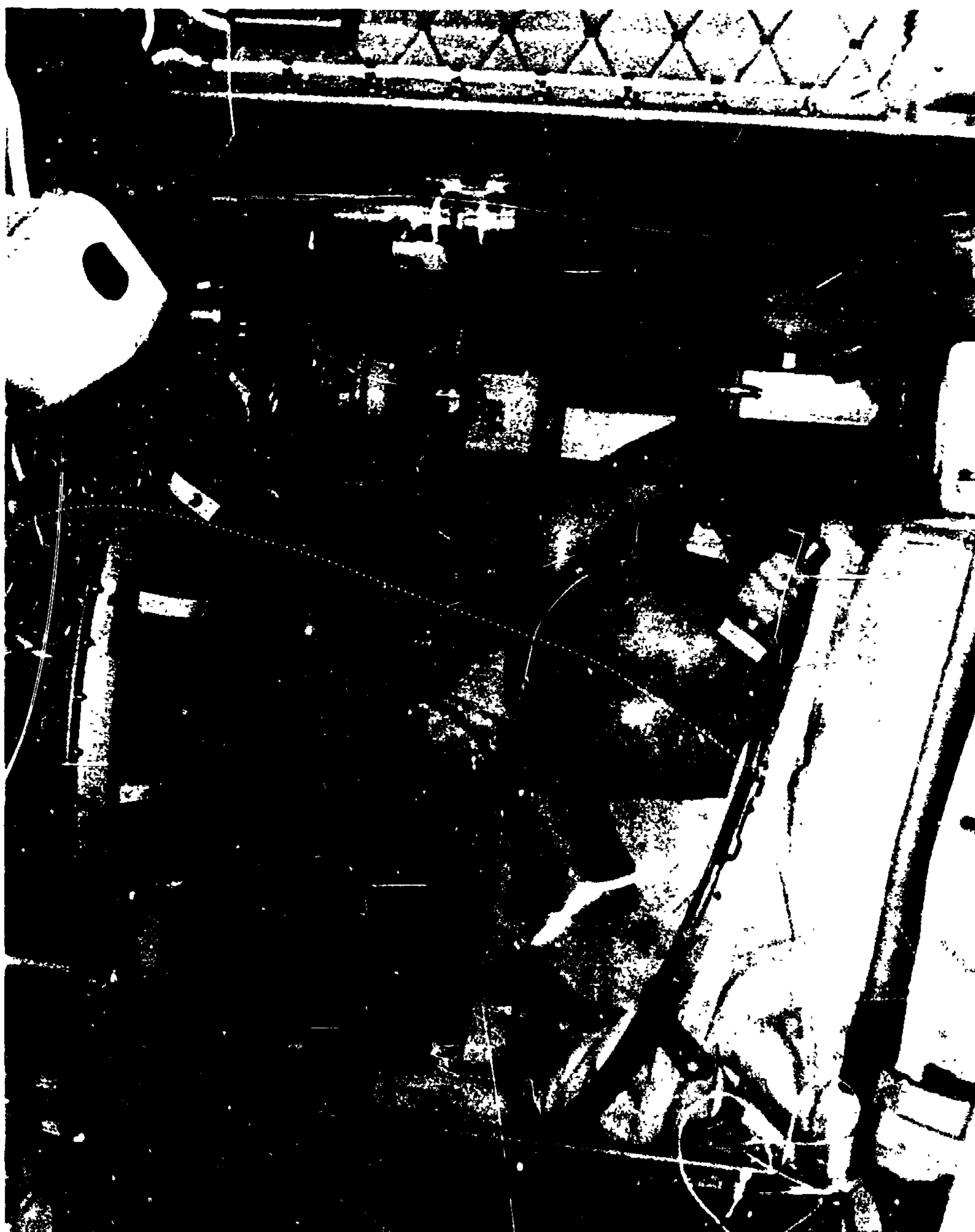


Figure 10-5.- Crewman showering.

the foods eaten in flight had a different taste from those used in the testing program. For example, the prime rib was better, but conversely, the tuna salad and several other items were much worse.

The mineral pills used for diet supplements were inconveniently packaged in metal books that would not slide in and out of the drawers easily. The pill containers which were glued to metal pages made separation of the pages difficult.

10.8.2 Experiment M092/M171 - Lower Body Negative Pressure/Metabolic Activity

A known problem exists with experiment M092/M171 (fig. 10-6) in that the iris does not close sufficiently to seal crewmen with the smallest waists. The time constraint resulted in a significant operational impact in that the time for other experiments had to be adjusted to accomodate this experiment. The solution was therefore undesirable for experiments other than the lower body negative pressure/metabolic activity experiments sequence.

The subjective impression of the crew is that the differential pressure of experiment M092 was greater than 50 millimeters of mercury. Since the reading on the experiment support system is from an independent sensor, this condition was probably only the subject's impression while in zero-g. Somehow, the subject is drawn further into the experiment equipment in flight and, therefore, feels more differential pressure than when on the ground. The saddle position must be raised two or three notches toward the iris to keep the body position the same as it was during the ground tests.

The blood pressure measurements were rather erratic, particularly at the higher systolic blood pressures observed during the metabolic activity experiment. This reduces the measurement's usefulness to the observer as an indicator of the subject's condition during metabolic activity experiment run. The crew's conclusion is that the best indication of when to terminate an experiment run comes from the subject himself rather than an observer. The subject's own sensations of sweating, dizziness, or approaching syncopy are earlier and more reliable than the indications based upon blood pressure and heart rates. The observer's presence is required as a safeguard.

The crew's performance in conducting metabolic activity runs continued to improve throughout the visit. The improvement is, to some extent, attributed to learning better ways of pedaling the bicycle in zero-g. The first problem that occurs is that the downward force (and torques) must be balanced by an equivalent upward force so that the crewman remains

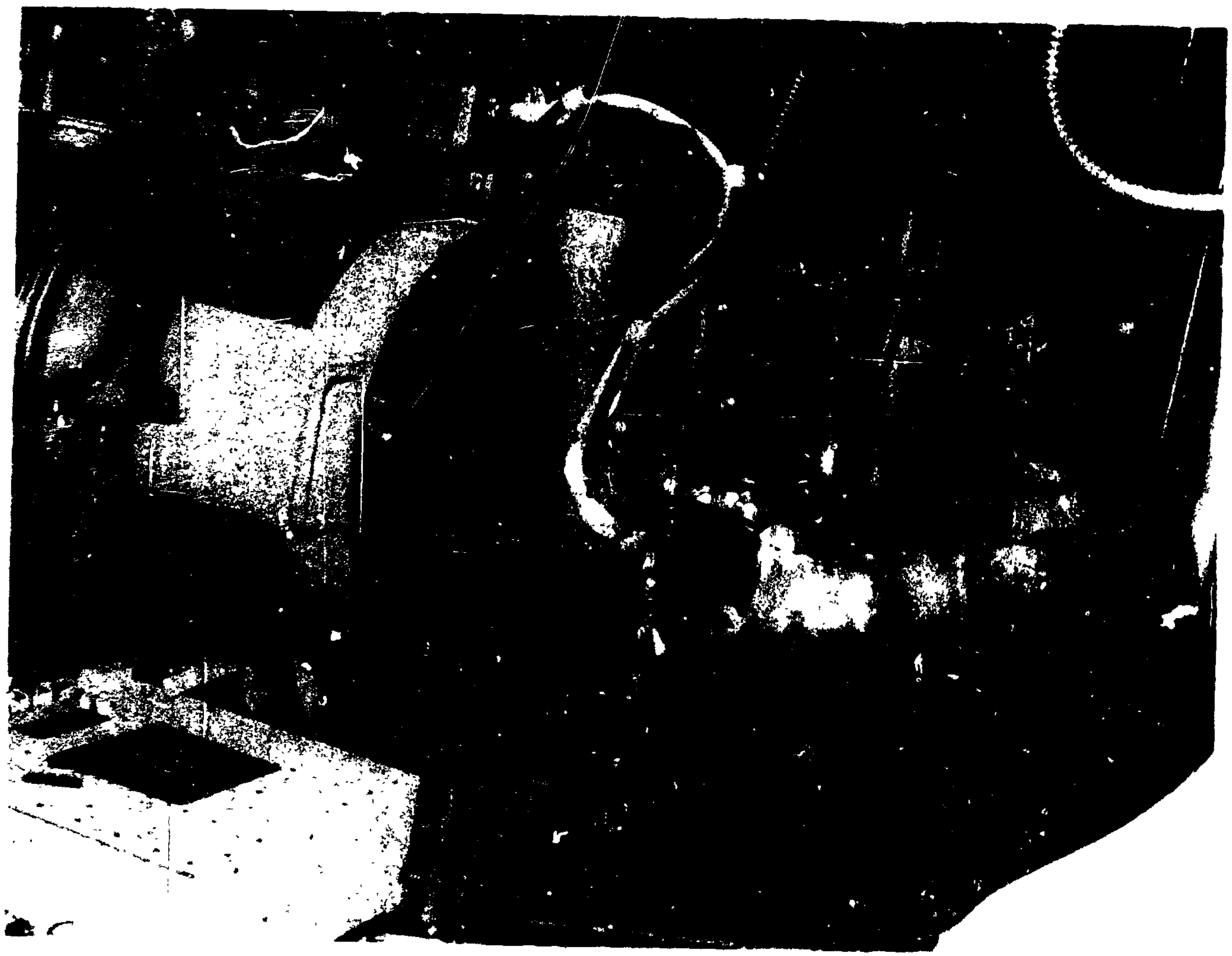


Figure 10-6.- Lower body negative pressure experiment in operation.

stationary on the bicycle. In zero-g, this balance can be accomplished in three ways: by counteracting the force with an upward force from the other leg, by holding on to the handle bars, or by bracing the head on the overhead with a cushion used as a pad between the head and a cable tray mounted to the ceiling (fig. 10-7). All three crewmen used these methods either alternately or simultaneously for all exercises. As a crewman learned to deliver torque on the upstroke, he found that he could relieve some of the forces required from the arms and the head by using a "new" set of muscles in the legs.

10.8.3 Experiment M172 - Body Mass Measurement

A significant improvement can be made in the accuracy of body mass measurement by using the shoulder straps in their locked position. However, some practice was required before the crewmen remembered that a continuous force is required to prevent the shoulder straps from unlocking. The measurement repeatability is significantly improved by tensing the muscles, particularly in the abdomen before the trigger is pressed, and then maintaining the tenseness until the measurement is complete. The trigger must be squeezed slowly, much as a trigger is squeezed when firing a rifle. The crew also noted that the results were usually more repeatable if, upon first arising in the morning, the machine was oscillated for 15 to 20 seconds before use.

10.8.4 Experiment M110 Series - Hematology and Immunology

In conducting the experiment M110 series, it was necessary to allow sufficient time for the Scientist Pilot to draw blood and to make the hemoglobin and specific gravity measurements. About 15 minutes were required the night before to lay out the hardware, and about 2 1/2 hours of the Scientist Pilot's time was required the following morning to make the blood draws, label the samples, centrifuge the tubes, place the tubes in the freezer, and then make individual hemoglobin measurements with separate evaluations of each sample recording. The separate evaluations required 5 or 6 readings with each eye on each of the samples. The specific gravity measurements also required a little additional time. The procedures and protocol for this series were good.

10.8.5 Experiment M133 - Sleep Monitoring

Experiment M133 (fig. 10-8) was performed by the Scientist Pilot and the final runs were scheduled for recovery day, and the second and fourth day after recovery. The crew believes this situation was undesirable because there are enough problems early in the postflight phase in readjusting to one-g without having to sleep with a tight cap containing a number

Figure 10-7.- Metabolic activity experiment in progress.

Figure 10-8.- Crewman in sleep compartment with sleep monitoring experiment.

of electrodes pressed against ones head. The crewman surely exhibited a lighter and more fitful sleep than he otherwise would have, and probably had a reduced amount of sleep. These disadvantages would make any conclusions concerning the level and the amount of sleep obtained on these postflight nights unrealistic as compared to the amount of sleep the subject would normally experience in one-g if he were not wearing the cap.

10.9 APOLLO TELESCOPE MOUNT EXPERIMENTS

Apollo Telescope Mount operations were rather close to the intended procedures. However, there were several problems. Because of an experiment S054 (X-ray Spectrographic Telescope) door problem which resulted in the loss of the talkback due to the door being pinned open on the first visit, a timer was used on the second visit to cue the operater as to when the experiment photographic exposures were complete. Another problem was that a monitor on the Apollo Telescope Mount control and display panel apparently failed, although the associated video circuits were apparently functioning properly.

The hydrogen-alpha 2 display occasionally appeared to expand and contract. This condition appeared only when the hydrogen-alpha 2 experiment was first turned on in the morning and it was readily corrected by zooming the scope in for about 5 seconds. The image would then stabilize.

The crew believes that the pointing stability of the experiment pointing system is much better than that specified and must be below 0.0000048 radian in both jitter and drift. A manual movement of the spar (using manual pointing control) of only 0.0000048 radian can be discerned on the television monitors when looking at hydrogen-alpha 1 or the S082B (Chromospheric Extreme Ultraviolet Spectrograph) white light display. Also, when the manual pointing control is not moved, no telescope reticle motion can be observed on the disc of the sun. This condition is true at all times, even when the crew is exercising vigorously.

The chair at the Apollo Telescope Mount control and display panel is an unsatisfactory feature which should be considered in future spacecraft designs. The chair is locked to the grid structure and it was intended that the operator strap himself to the seat so that his position would be much the same as a man sitting at a desk. Although the chair was tried on several occasions by all crewmen (fig. 10-9), the chair was not satisfactory because the operator had far more flexibility and a much greater reach simply by locking his feet into the gridwork and then extending or bending his legs, either together or one at a time, to reach from top to bottom or side to side. Operations were much more comfortable without the chair, and the crew believes that these comments apply to a much broader category of human factors design than simply the chair evaluated at the Apollo Telescope Mount control and display panel.

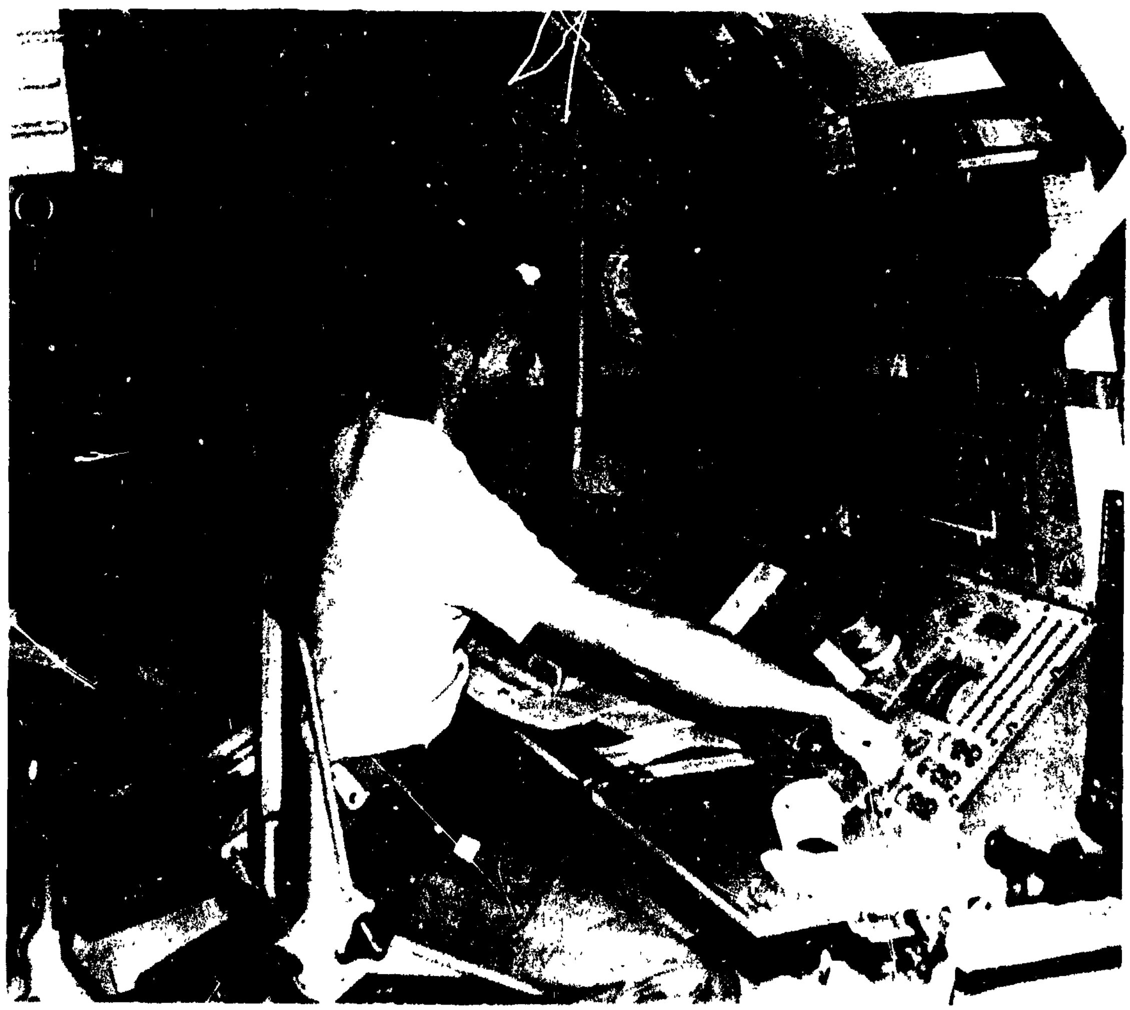


Figure 10-9.- Crewman at Apollo Telescope Mount control and display panel.

The crew found that Polaroid photographs of the Apollo Telescope Mount displays were of considerable help in evaluating transients which were encountered during the day's operation. Early on each operating day three good photographs should be taken of: the white light corona, the extreme ultraviolet monitor, and the hydrogen-alpha 2 display. The photographs are most useful with the sun centered. The coronal photograph is very helpful in establishing the existence of transients (fig. 10-10) or alterations to the structure of the corona. The extreme ultraviolet monitor photograph is useful for finding the location of bright spots and the orientation of coronal holes, and for observing connections between separated active regions. The hydrogen-alpha photograph is valuable as a reference in identifying solar features and for comparison with the extreme ultraviolet picture. Additional photographs from these three principal sources may be taken more than once, but a minimum of the three taken early each day is desirable.

The persistent image scope was of great value in working with the extreme ultraviolet monitor. The sensitivity of the extreme ultraviolet display was so low that only the very brightest active regions could be discerned without integration. Use of the persistent image scope allowed somewhat fainter objects to be discerned without integration and, by integrating, even fainter images were retained for a longer period. This allowed the operator to point at individual features such as the bright spots or coronal hole boundaries. As a special technique, the crew coaligned the electronic cross-hairs with the hydrogen-alpha 1 mechanical reticle, thus allowing the extreme ultraviolet monitor display to be used to place the slit center on a specific small region, such as a bright point, for experiments S055 (Ultraviolet Scanning Polychromator Spectroheliometer) and S082B. The special technique was especially useful in accomplishing the various objectives of Joint Observing Programs 15, 17, and others. In general, this sort of a scope is a desired feature for observing very faint or transient images.

The organization of Joint Observing Program 3 for the second visit was satisfactory for solar flare observations. Any available cue was used to alert the crew to the possibility that a flare was in an early phase. These cues might have been a rise in the count of the photomultiplier exposure counter, or increases in the counts of the image intensity as the beryllium counters. Also, visual indications from the hydrogen-alpha monitor, the extreme ultraviolet monitor, or even a radio noise burst were used. From whatever source the initial alert may have come, the existence of a flare could be confirmed by cross-comparing the various displays and counters. The existence and location of a solar flare was never in doubt to the crew, as long as the flare indications exceeded the flux threshold sent up from the ground. In the majority of cases, by the time the photomultiplier exposure counter exceeded the uplinked flux threshold, the operator was already aware that a flare was in progress (using

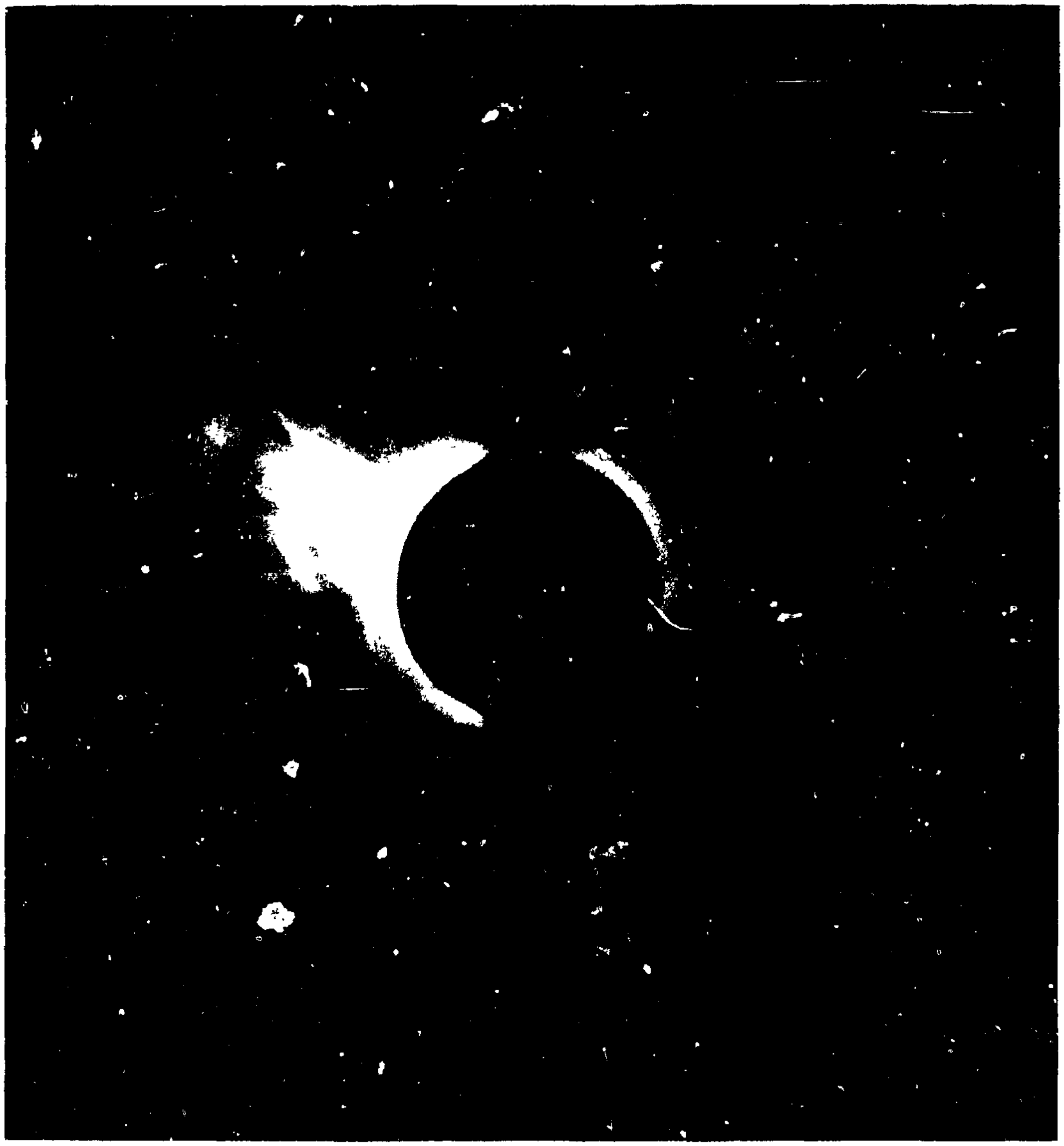


Figure 10-10.- White light coronal transient.

one or more of the various onboard sources) and he was simply waiting for the required threshold to be exceeded before initiating the appropriate action. Experiments S055 and S056 (Dual X-ray Telescopes) were usually already operating as there were no restrictions on the initiation times.

Joint Observing Program 13, on nighttime sources, was performed only once, but the ground-based pad seems to have been designed very precisely. The entire operation was executed almost exactly as planned and within the times alloted. The pointing was very near the correct location, although the gimbal angles of only the second star were known. The initial data results from experiment S056 show that the X-ray source Sco-X was observed by the wide-angle detectors and X-ray photographs from experiment S054 may also show this X-ray source. This same procedure should be used for Comet Kohoutek observations, and other nighttime sources as well.

The shopping list flight plan items, received periodically from the ground, were of great assistance in providing flexibility to crew operations at the Apollo Telescope Mount and in making the most efficient use of small amounts of time (5 or 10 minutes) that the operator would occasionally have after completing the planned tasks for an orbit. The two pages of shopping list items for the second visit were generated only within the last few weeks prior to flight. Yet, the list provided the crew good flexibility in selecting short programs for study of active regions, bright spots, coronal holes, limb features, and other interesting events. The list was one of the most important reasons why the crew was able to make nearly optimum use of almost all the time available when the line of sight was above 400 kilometers.

10.10 EARTH RESOURCES EXPERIMENT PACKAGE

The Earth Resources Experiment Package operations were conducted as planned, although more passes were actually performed than were planned. Cue cards were used in preparing for a pass as well as during post-pass operations. The data-take portion of each pass was performed according to daily teleprinter information which was transmitted from the ground. The time required for the pass preparation and the post-pass operations was reduced significantly as experience was gained during the visit. A total of 26 Earth Resources Experiment Package passes were planned prior to the visit, but 39 were actually accomplished.

All Skylab attitude maneuvers were controlled by the Apollo Telescope Mount computer, and ground personnel generated all of the maneuver solutions. Typically, the maneuver parameters were loaded into the computer by the crew in time to be verified by the ground prior to initiating

the maneuver, thus minimizing usage of the thruster attitude control system propellant during the maneuver. An easier crew operation would have resulted if the ground personnel had also loaded and initiated the maneuvers as a general practice. The crewmen could then have focused all of their attention on the operation of the experiment equipment without interruption or diversion. After the first few Earth Resources Experiment Package passes of the visit, the star tracker partially malfunctioned and the decision was made to no longer use the star tracker for position information.

Occasionally, the weather forecast was inaccurate and the instruments would be operating when the ground was obscured by clouds. Onboard capability existed to determine when the desired sites could be obscured and the crewmen should have been given more flexibility and latitude in determining when the instruments should have been operated. This applies to the instruments operated from the control and display panel as well as site selection through the viewfinder tracking system.

Another system design shortcoming was that no means existed for real-time crew transmission of earth resources data to permit the ground personnel to optimize data requests. Future systems should take better advantage of the capability of the man onboard the spacecraft, permitting him to make real-time decisions on whether or not to take data and to give him the capability to optimize the data which are being received.

10.10.1 Experiment S190 - Multispectral Photographic Facility

The S190A experiment film magazimes were affixed to the camera stations for every pass with no difficulty. The film magazines were loaded with film cassettes when the film was depleted, and although this was a time consuming task, it was accomplished without difficulty. Film streaks were noted to build up gradually on the experiment S190A film platens. The platens were cleaned periodically with water and were rapidly dried with a lens tissue to prevent water marks.

Desiccants were used with the experiment and required replacement every 2 or 3 days. The desiccants became saturated after this length of time, appearing white or blue-white. Sometimes the desiccants that were removed from "sealed" containers had turned white, but when they were dried in the fecal driers in the waste management compartment for approximately 50 hours, the color was again a royal blue.

Some contamination had built up on the interior lenses of the experiment cameras, and there were some scrape marks on the outer shutters. The amount of contamination was proportional to the amount of abrasion on the outer shutters, making it apparent that the contamination came from the shutters rubbing within the housing.

10.10.2 Experiment S191 - Infrared Spectrometer

The selected onboard maps and photographs of the experiment S191 sites were adequate. Prior to flight, the viewfinder tracking system simulator was used extensively for each site and almost all of the sites were also viewed by both crewmen from a T-38 aircraft to familiarize them with the sites. This double training technique is highly recommended for future crews.

Clouds and haze presented the major problem in acquiring sites. Besides the obstruction which a cloud itself presented, the cloud shadow cast on a site increased the difficulty of identification, even though the site was in plain view. The acquisition and tracking of small sites on the ground was feasible and simple, if clouds were not too numerous.

The image motion compensation drifted slowly after being targeted on a site, but did not present a problem as long as the operator did not remove his eye from the viewfinder.

As the visit progressed, the door which covered the experiment S191 optical system required more time to open and close, and moved in a jerky fashion as opposed to operating smoothly through the length of travel. A decision was made to leave the door open for the remainder of the visit. During this period of time, no contamination was observed on the optics that degraded the capability to view the ground. The door was closed prior to undocking and, although it appeared to close, it did not do so completely. This was deduced by the fact that the alignment system could not be actuated to align the telescope optics with the spectrometer. The door was apparently not striking the limit switch upon closure, and thus, not actuating the alignment electronics. The last alignment check prior to the failure, however, was acceptable and no reason existed to believe that the alignment had changed. Section 4.3.3 contains a discussion of this problem.

An offset existed in the zoom optics such that the cross hairs aligned with slightly different locations when the zoom was varied. The offset of the zoom lens caused a minor problem in acquiring and tracking several sites within a multiple-site area because of the necessity to track the sites at maximum zoom so that the spectrometer would be pointed accurately. In order to acquire another site in the same area, it was necessary to return to a lesser zoom setting to initially find the target, and then return to maximum zoom to track the target. Had this condition not existed, more sites in a multiple-site area could have been acquired. Several sites would have remained within the field-of-view at one time, and they could have been tracked at a setting of less than maximum zoom.

10.10.3 Experiment S192 - Multispectral Scanner

Experiment S192 was very difficult to align during the first visit and the detector outputs were not maximized. The initial inspection by the second visit crew showed that the cooler-detector was not seated properly. The cooler-detector was removed, reseated, and realigned, and the sensor performance was maximized.

10.10.4 Experiment S193 - Microwave Scatterometer/Radiometer

The experiment S193 antenna action became erratic and finally failed during the second visit. Photographs were taken of the antenna during operation to demonstrate this behavior. This failure is documented in section 17.2.5.

10.10.5 Earth Resources Experiment Package Tape Recorders

Tape recorders 1 and 2 exhibited no deviations from the performance observed on the first visit. They were easily cleaned and loaded. A newly loaded tape recorder required a very careful check to insure a properly loaded condition before closing the cover. The cleaning procedure was accomplished after every Earth Resources Experiment Package pass and, generally, the tape recorder stayed quite clean.

10.10.6 Earth Observations

A program of earth observations was initiated midway through the second visit. This series of observations, consisting of requests to photograph and describe the land features of certain areas around the world and weather phenomena (figs. 10-11 and 10-12), was not planned preflight. Ground and aircraft observations of some of these areas had already been made; however, an objective was to define these areas more completely from orbit. This objective was not completed to the crew's satisfaction, but is one of the more important studies that can be made on future flights.

In several cases, the onboard maps were not sufficiently detailed to locate the features for which observations were requested. This exercise showed that locating and photographing most sites is not difficult if the proper maps are available. The exercise also showed that these sites at which the spacecraft passes over the ground is too fast to be able to recognize the subtleties which are present.

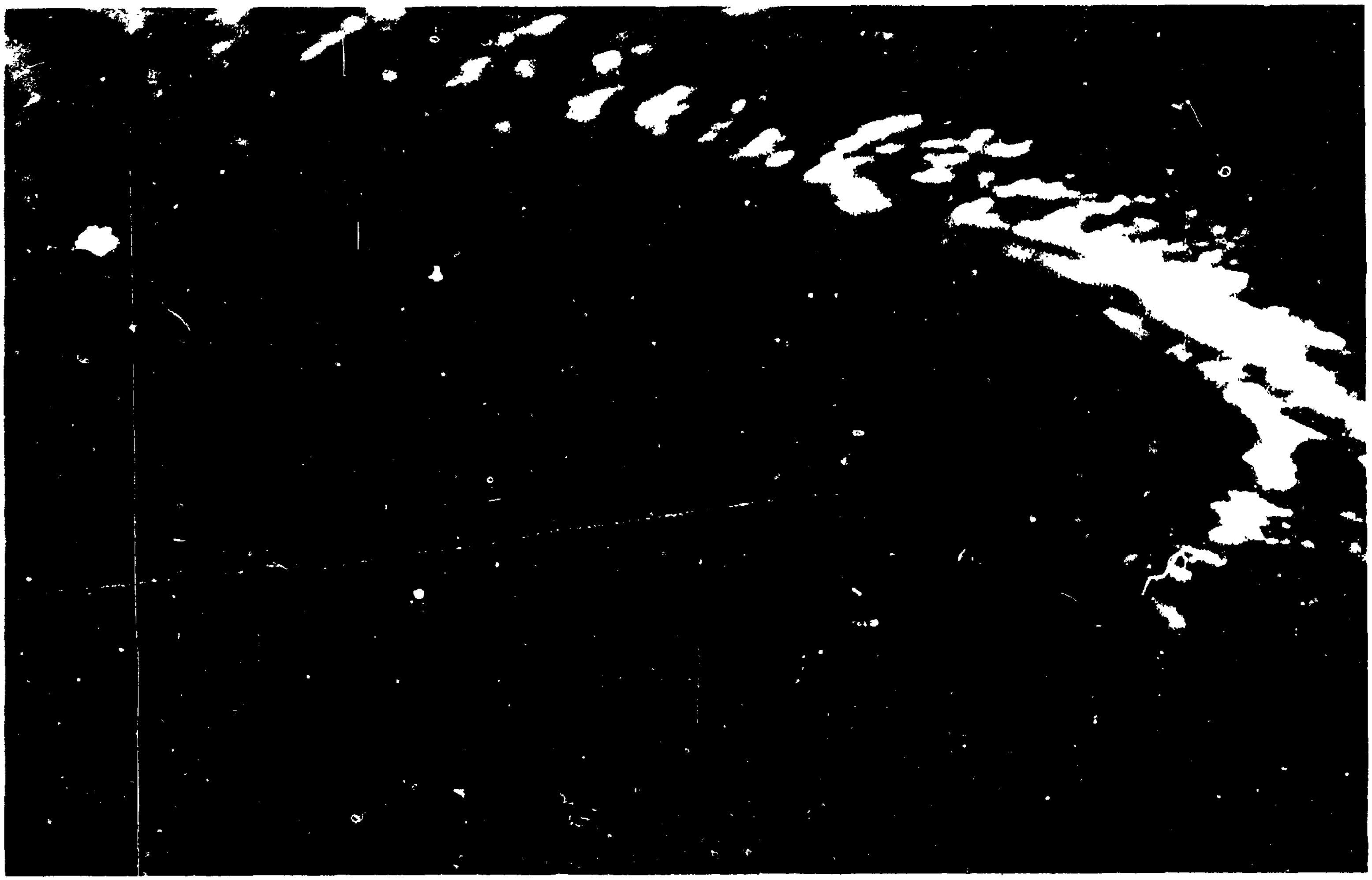


Figure 10-11.- Unique storm vortex photographed during second visit.

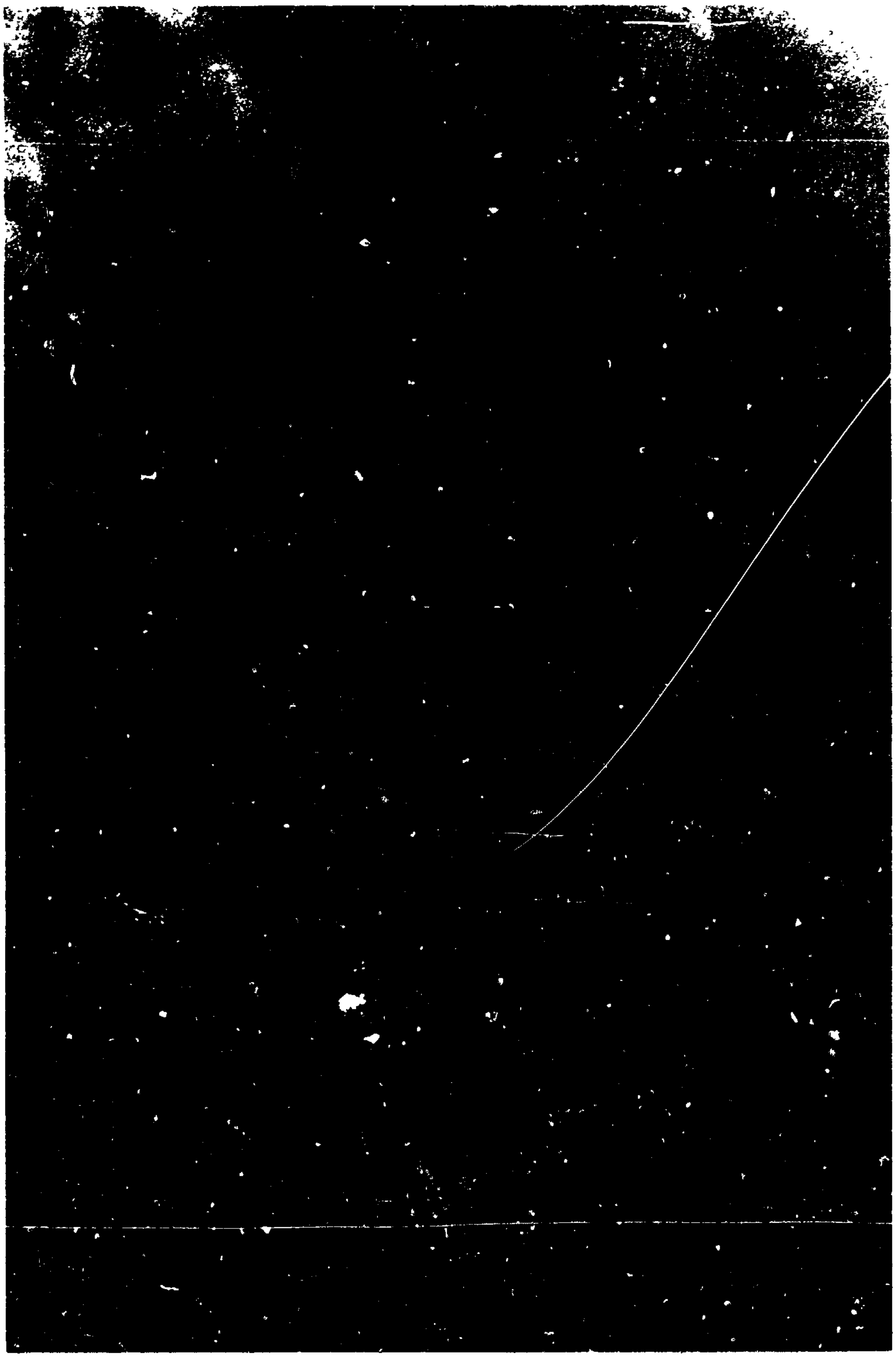


Figure 10-12.- Storm vortex and eye.

If visual observations of an area are to be relied upon rather than photographs, specific questions should be asked in a systematic manner rather than asking general questions. Experience has shown that several passes over an objective area are required for proper observations because of the short time the site is visible on any one pass.

Besides matching detailed earth observation questions with adequately detailed maps, some hardware improvements are desirable. Binoculars of higher magnification should be attached to a fixed mount containing manual tracking capability. Additionally, an instrument would be useful for accurately determining the size and the distance of various land forms and cloud systems.

Four structural transition section windows and the wardroom window were available for earth observations. The view from any of the structural transition section windows was restricted because these were very small and vision was obstructed by Workshop structure. The wardroom window was not oriented in the optimum directions during a major portion of each orbit because of the spacecraft attitudes. The pane thickness of the wardroom window also effectively reduced its size, and often a site at the nadir was not observable because of the effects of beta angle. Larger bubble-type windows at several locations are desirable so that unrestricted observations may be made without regard to spacecraft attitude.

Finally, the crew believes that hand-held photography and earth observations should have received greater stress. Within a variety of disciplines, properly exposed photographs of carefully selected sites would be of considerable value. Many of the objectives would be similar to those of the earth resources exposures, but hand-held photography provides much greater flexibility and many additional opportunities.

10.11 COROLLARY EXPERIMENTS

This section presents comments of an operational nature on two corollary experiments - M509 (Astronaut Maneuvering Equipment) and T020 (Foot-Controlled Maneuvering Unit). The principal investigators' reports will discuss much of the actual data that was derived through telemetry and photography, whereas this report contains the operator's evaluation of this type of equipment under extravehicular activity conditions.

10.11.1 Experiment M509 - Astronaut Maneuvering Equipment

The astronaut maneuvering equipment was an excellent means of investigating various design aspects of manned maneuvering units. The equipment (fig. 10-13) was operated in each of the four control modes; control moment gyro, rate gyro, direct, and using a hand-held maneuvering unit.

The control moment gyro mode was by far the most stable and the most luxurious of the four modes, plus being an easy mode to fly. The operator could maneuver to any desired attitude and hold that attitude accurately without further effort. Because of the precise attitude-hold feature in this mode, accurate translations or exact stationkeeping could be performed. The momentum capability of the control moment gyro, although not large, did allow a considerable amount of body motion or maneuvering before desaturation maneuvers were required. These desaturation firings were not unpleasant, but were felt as a slight transient in the backpack. One crewman flew the astronaut maneuvering equipment in orbit without any previous practice and found that, for him, the control moment gyro mode was the most straightforward of the operational modes.

The rate gyro mode provided a rather loose and drifting attitude-hold capability. The mode was distracting in terms of unanticipated thruster firing; however, large amounts of fuel were not used because the thruster firings were much shorter in duration than were possible by manual control. The rate gyro deadbands appeared to be slightly tighter than desirable because any inadvertent arm or leg motion would result in a considerable number of thruster firings. A wider deadband would have reduced the number of inadvertent firings. The inadvertent firings were not present in the direct control mode where head, arm, or leg motions resulted in movement of the man/vehicle combination; however, when the head, arm, or leg was returned to the original position, the man/vehicle combination would return to the original position. No propellant was expended in the direct mode for these limb/body motions, whereas a considerable number of firings occurred both with the initial motion and with the return motion in the rate gyro mode.

Stationkeeping was possible without thruster firings by holding lightly to the side of the Orbital Workshop, even in control moment gyro or rate gyro modes. However, if any torque was exerted on the vehicle by the crewman, thruster firings would result, but firings could be prevented by being careful. The best technique to perform work at a site was to fly near the site and, just before taking a hold at the work station, switch the astronaut maneuvering equipment into the direct mode. Work could then be accomplished just as if no astronaut maneuvering equipment were being worn.

Figure 10-13.- Astronaunt maneuvering equipment experiment in operation.

The direct mode was the simplest of all modes and appeared to possess all of the capabilities needed in maneuvering equipment. However, the equipment was not as easy to fly as in the control moment gyro and rate gyro modes. Although more attention was required when flying in the direct mode and the equipment could not be flown as precisely because of the difficulty in commanding small impulse thruster firings, it was nevertheless a relatively simple and intuitive task. Also, the amount of time or mental activity required either to hold attitude or to make translations was not unacceptable. The direct mode had the great advantage, during pressure-suited operations, of allowing a control input to be made to change attitude, but not requiring the controller position to be held throughout the manuever. Releasing the hand controller and relaxing the hand during the maneuver was a significant advantage.

The hand-held maneuvering unit was marginally controllable, but flyable. If the operator would accept considerable attitude deviations and concentrate primarily on translating, point-to-point flying could be accomplished. The hand-held maneuvering unit could not be flown intuitively. Each control input had to be carefully thought out. The total ability to correct attitude or translation deviations was small and the degree of difficulty was not unlike trying to walk a tightrope or ride a unicycle.

The astronaut maneuvering equipment was first flown in the unsuited intravehicular activity mode. The unsuited tests were most useful in evaluating the simplicity of control and the relative capabilities of each system. Suited runs were performed in an effort to evaluate the system as it would be used during extravehicular activity. Several differences were obvious between unsuited and suited operations. The first were the disturbing forces introduced by the oxygen, water, and communication umbilical. This umbilical was relatively stiff and it prevented precision flying of the astronaut maneuvering equipment in any mode. This umbilical created two effects on operations. First, the umbilical had a certain position that it wanted to retain, possibly because of the manner in which it was stowed, and any effort to move the umbilical from this position required an expenditure of fuel, particularly in the rate gyro mode. The second effect on operations occurred once the umbilical was in motion. Because of the momentum developed as it moved and the fact that the center of gravity of the umbilical was not near that of the thruster system, the umbilical would continue to move when an attempt was made to stop the overall system. The result was the use of additional fuel and the occurrence of attitude and translational overshoots. The overshoots were particularly troublesome when flying the hand-held maneuvering unit where several firings of thrusters would result in, perhaps, a slight motion, with the next thruster firing causing an increased response completely out of relative proportion to the amount of attitude control put in. The same thing would occur during stopping. Attitude

and translational corrections would be made with little effect and, suddenly, one would seem to take effect and generally overcorrect the situation. When using the hand-held maneuvering unit during suited operations, a standard response could never be obtained for a standard input.

Prior to the second suited test, a standard umbilical was modified by removing the beta-cloth covering, the two water hoses, the tether, and all of the electrical wiring. This umbilical proved to be acceptable for maneuvering in that it did not induce the perturbations of the original umbilical. The lack of communications was a real disadvantage and this should be corrected prior to the next visit either by modifying another umbilical with the wiring left intact, or by attaching a lightweight crewman communications umbilical to the present stripped-down umbilical.

Prior to the flight, the crew believed that the best way to use the hand-held maneuvering unit was to push off the wall in a desired direction and use the hand-held maneuvering unit only for midcourse corrections. This method of operation was evaluated and was unacceptable because the attitude disturbances accidentally introduced when pushing off were generally too large for the hand-held maneuvering unit to rapidly correct. The fact that the hand-held maneuvering unit is not controlled by intuition or by logic similar to other flight or ground vehicles made this device unacceptable for use during extravehicular activity operations.

In the suited mode of operation, flying with the hand-held maneuvering unit was more difficult than was expected from experience on the 6-degree-of-freedom simulator. The large suit area caused greater thruster impingement effects than were predicted in training. The impingement effects made placement of the hand-held maneuvering unit in the right location for a pure translation almost impossible. The impingement effects never caused a crewman to lose control; however, flying was considerably more difficult because of the impingement factor.

Simulated crewmen rescue, using the astronaut maneuvering equipment as the rescue vehicle, was easier to perform in the rate gyro or control moment gyro modes because translation of the off-center-of-gravity configuration did not require special hand controller activity. Attempting rescue in the direct mode was satisfactory; however, more hand controller manipulation was required. Attempting to fly to and stop in front of an object in space required some preplanning. Approaching a lightweight or small object directly was difficult because thruster impingement, as the astronaut maneuvering equipment was braked to a halt, caused the object to tumble and move away. However, an object that had a considerable mass would not have so pronounced a movement. One workable technique was to reduce the closing speed well away from the target, and then continue slowly until contact, without braking.

An attempt was made to match the rotational speed of a slowly rotating body. This proved impossible without excess fuel consumption because even small rotation rates resulted in random thruster firings which blew the rotating body away from the crewman.

A test was made to minimize fuel consumption by using the hands and feet to push off in the general direction of the next check point (similar the previous hand-held maneuvering unit test) and then use the astronaut maneuvering equipment as a midcourse correction device only. This technique proved to be simple, but it seemed (at least subjectively) that just about as much fuel was required as flying from point-to-point in the normal completely controlled manner.

Several tumble recoveries were attempted with excellent results. Although separating the rotation from translation was sometimes confusing at high tumble rates, the technique of stopping all apparent rotation and then using the translation controller to null translational motion was the easiest method to use. Trying to arrest both motions at once resulted in some confusion and, probably, is not the best method of operation. Stopping a tumble with the hand-held maneuvering unit was surprisingly easy, even in the suited mode. The ease came as a pleasant surprise, an extravehicular activity transportation device.

The astronaut maneuvering equipment restraint system had to be cinched up tighter than had been thought preflight. When the crewman was not restrained rigidly to the astronaut maneuvering equipment, the thrusting of the backpack would result in relative motion between the equipment and the crewman. This condition was undesirable in that the operator no longer felt like an integral part of the astronaut maneuvering equipment, but felt as though he was riding the device.

A typical flight test report would comment on the harmony of control forces and the resulting translational and rotational rates. A variety of control modes, combined with a variety of weights and center of gravity locations, resulted in continually differing harmony. The crewman adapted rather rapidly to any of these various combinations and, after a few minutes, was satisfied with each combination. Less than optimum combinations of control forces probably resulted in more concentration being needed to fly the vehicle and probably increased the fuel consumption, but neither was significant. It would have been desirable to be able to command smaller rotational and translational rates than was possible with the present equipment.

The environmental conditions introduced by such perturbing forces as Workshop motion and air currents within the Workshop did not prove to be of any significance. When compared with the available control authority,

the perturbing forces were so small that any maneuvering equipment that could not easily overcome disturbances of this small magnitude would not have acceptable maneuvering authority in its own right.

The astronaut maneuvering equipment, inflight, flew almost exactly like the 6-degree-of-freedom simulator. The absence of gravity cues in flight made maneuvering even easier. The astronaut maneuvering equipment probably flew like the air bearing trainer too, if the operator would have restricted himself in flight to operating in two dimensions with three degrees of freedom. The operator did not do this because it was too artificial. Because of this condition, the air bearing trainer should be eliminated from training as not only redundant to the 6-degree-of-freedom simulator, but also because no unique skills were taught that were used in flight. If a future astronaut maneuvering unit is so difficult to fly that a simulator is required, the air bearing trainer will not provide that training.

Crew analysis shows that the most desirable configuration for future maneuvering equipment would be without a tether, but with sufficient system redundancy in the equipment to correct for any single-point failures (for example, circuit breaker isolation for critical electrical components, switch/solenoid valve isolation for propellant valves and, of course, 6-degrees-of-freedom). The total of these would make it possible to maneuver with reasonable failures and still provide the level of safety required during extravehicular activity operations.

The future astronaut maneuvering unit, regardless of the mode of operation (rate gyro, control moment gyro, direct, or a combination), should be designed to be controlled and flown like a spacecraft. The correct responses would be the intuitive pilot reactions, and the reaction of the systems in an off-nominal failure situation would also be familiar. Preflight training would be performed on a 6-degree-of-freedom simulator with most of the emphasis given to operating in off-nominal attitude and translational modes.

10.11.2 Experiment T020 - Foot-Controlled Maneuvering Unit

Evaluation of experiment T020 (fig. 10-14) revealed two major deficiencies. One, the experimental unit lacked 6-degree-of-freedom operation, so that it was frequently impossible to go where one wanted, and two, precise control with the feet, particularly in the suited mode, was not possible.

For the same reasons that an airplane is not flown primarily with the feet or a car is not driven primarily with the feet, the foot-controlled maneuvering unit could not be flown as well as a unit having a hand controller. No advantage was apparent for operating a maneuvering unit with

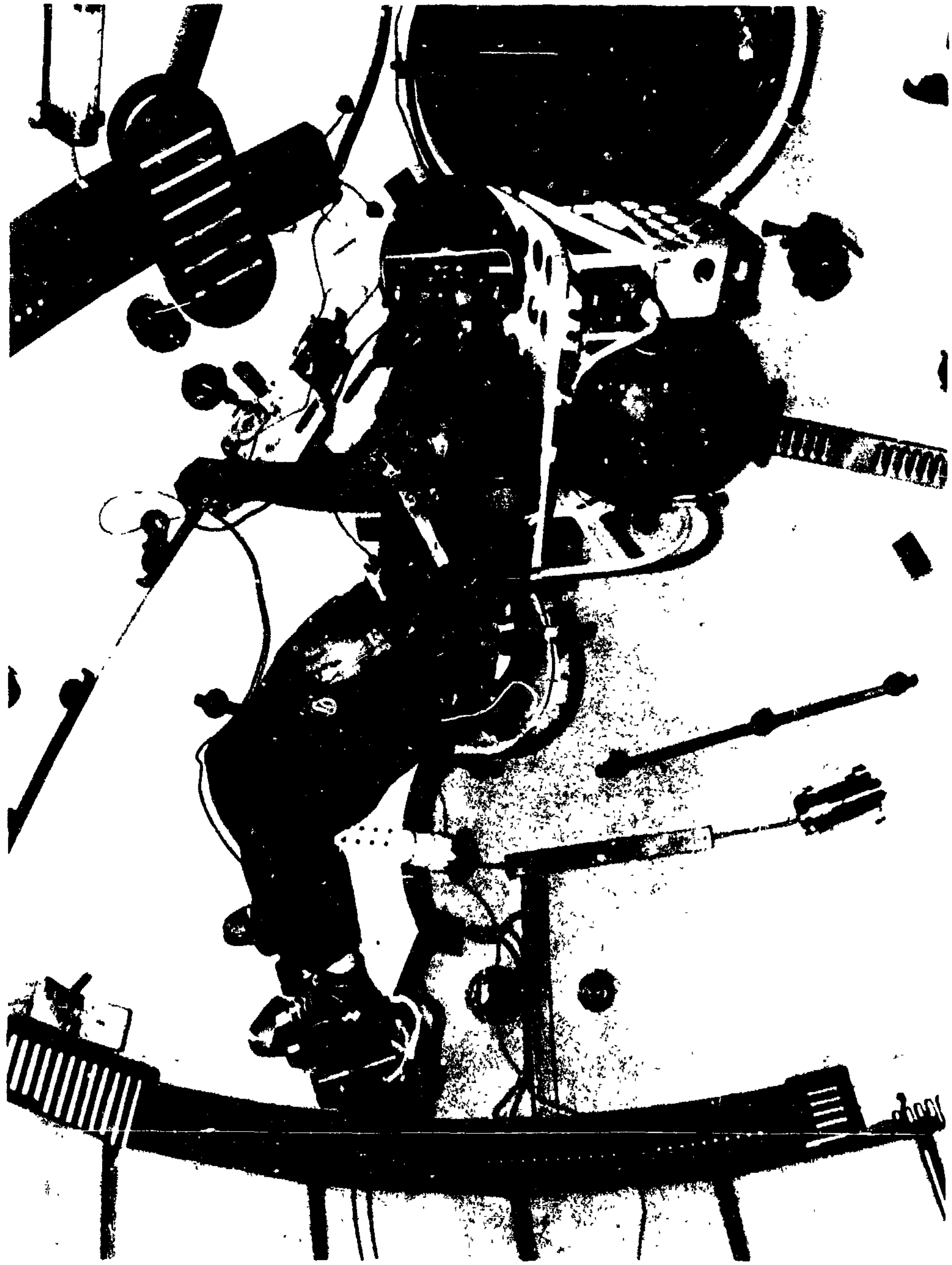


Figure 10-14.- Foot-controlled maneuvering unit in operation.

the feet, although the suggested reason was keeping the hands free to do useful work This logic did not prove true, since the backpack-type maneuvering units with foldable arms did not unduly hinder simulated work at a typical site. Types of work that could be performed using the foot-controlled maneuvering unit could also be performed using the astronaut maneuvering equipment hand controller unit.

The lack of six degrees of freedom, with the capability of translating only toward the head or toward the feet, was most frustrating. The only way that a target could be reached was to start when almost completely stationary with the feet pointed at the target. If the initial thrust were not exactly toward the target, some lateral translational velocity was introduced. The lateral translational velocity could not be removed before missing the target in about one third of the attempts. Further, the lack of 6 degrees of freedom made stopping at any desired place within the Workshop completely impossible once any motion had been introduced. Rotational or translational corrections to null a velocity would result in other translations or rotations about the same or other axes which then had to be corrected. Consistently stationkeeping or flying to a desired destination was just not possible with the foot-controlled maneuvering unit.

The operational evaluation showed that translation could be best accomplished in a feet-first direction. Although, if the crewman wanted to hold onto the work station upon arrival, a pitch-down maneuver was necessary en route. The pitch-down maneuver, however, caused the legs to sweep an area that could not be viewed by the crewman. Thus, there was no protection against accidental contact with other parts of the Workshop. Accidental contact occurred on several occasions, even though the interior configuration of the Workshop was well known. In extravehicular activity situations, the external protuberances might not be so familiar, and striking a sharp edge in a pressurized suit could have a pronounced effect.

Physical operation of the foot controls in flight was more difficult than in training because the forces required to fire a thruster would cause relative motion between the maneuvering unit and the crewman. In simulations, these forces were not so noticeable, since they were masked by gravity and friction. Any attempt to tighten the crewman to the foot-controlled maneuvering unit to prevent relative motion in the unsuited mode caused pain in the crotch and seat area. In the suited condition, the suit was tight, but the crewman was sufficiently loose inside the suit to move up and down inside the suit. Consequently, the crewman would bang his buttocks against the bottom of the suit on an upward translation command and bang his shoulders on the top of the suit during a downward translation. However, a comfortable pressure suit must not fit too tightly, and some of this body-float problem could probably be eliminated with a decrease in the force and travel required to operate the foot pedals.

Cross-coupling was also a problem since roll disturbances were introduced with yaw commands. In manually counteracting the unnecessary roll, a further cross-couple disturbance was introduced. There were an inordinate number of nonproductive control inputs necessary for all maneuvers, and they were particularly noticeable in yaw.

Because of the impossibility of being able to stationkeep or fly to the desired destination consistently, the crew believes that the T020 foot-controlled maneuvering unit embodied design principles that are unsafe for use during extravehicular operations.

10.12 STUDENT EXPERIMENTS

The comments relative to the student experiments are limited to those experiments having separate hardware.

Student experiment ED32 (In vitro Immunology) appears to have worked quite well and the photographs show the growth rings clearly. Also, student experiment ED52 (Web Formation) seems to have been quite successful in spite of malfunctioning of the electronics that were to have triggered the cameras during web formation (fig. 10-15). Although no web formation data could be obtained, a number of daily photographs of the various webs were taken and these should permit very extensive analysis and interpretation of the spider activities.

Student experiment ED63 (Cytoplasmic Streaming) was not particularly successful because the plants were apparently nonviable at the time the experiment was initiated. Apparently, insufficient ground-based testing was conducted to assure that the plants would be alive after being stored for the length of time and under the lighting conditions that would be required in the Orbital Workshop. Improved ground-based testing should have been performed to prevent or avoid this difficulty. Similar comments apply to student experiment ED78 (Liquid Motion) which was attempted on the second visit. The pressure within the bubble chamber had already been released at the time the trigger was depressed. An attempt was made to repressurize the container with the device provided, but the diaphragm broke, incapacitating the whole unit. After flight, the crew learned that ground-based testing had shown that a broken diaphragm was a possibility if not a probability, and this information should have been communicated to the crew.

Figure 10-15.- Spider web formation.

10.13 EXTRAVEHICULAR ACTIVITY

The three extravehicular activities (fig. 10-16) of this visit were performed on visit days 10, 28, and 56. Each extravehicular activity required two crewmen for the extravehicular operations plus one partially suited crewman in the Multiple Docking Adapter with the responsibility of coordinating the extravehicular activity procedures and tending the spacecraft systems.

Extravehicular activity preparations were performed the night preceeding the extravehicular activity whenever possible, and this was a desirable way to operate. The extravehicular activity preparations were much easier in zero-g than in one-g. Suit donning was also much easier in zero-g than in one-g, except for the outer zipper around the back of the suit, which was more difficult to close than in one-g. A donning lanyard for the back zipper would ease the suiting problem. The crewmen were late in egressing on all of the extravehicular activities. Depressurization of the airlock was accomplished normally on each extravehicular activity. The screen for collecting the ice on the depressurization valve worked well. Ice up to about the size of a quarter would collect on the screen and then grow no larger, permitting the gas to flow around the ice and out through the valve. Particles inside the airlock compartment migrated toward the depressurization valve, thus making it wise to insure that the airlock compartment was free of debris before extravehicular activity operations were begun.

10.13.1 First Extravehicular Activity

The first extravehicular activity included the erection of the twin-pole sunshade, Apollo Telescope Mount film installation, installation of the S149 experiment (Particle Collection), attachment of the experiment S230 (Magnetospheric Particle Composition) clips, removal of an Apollo Telescope Mount experiment door ramp, and various inspections of the spacecraft for coolant leaks, discolorations, etc. The two poles which formed the structure of the twin-pole sunshade each came in eleven 1.52-meter sections. The 1.52-meter sections were mounted on racks and held down by elastic which frequently slipped into a depression in the sections, making them difficult to remove from the racks. Both poles were assembled and inserted into the base plate with no difficulty.

About 1 to 2 minutes were required to move the pole through the 1.53 radians of travel. One of the lines on the second pole was wrapped completely around the pole, and the pole was removed and returned to the crewman near the hatch, where the pole was taken apart at one joint and reassembled so as to straighten the line, and then replaced in the base

Figure 10-16.- Loading Apollo Telescope Mount film during extravehicular activity.

plate. The sun shade was folded very compactly in accordian fashion in its stowage bag. As the shade came out, the paint covering the sunshade tended to stick to itself in the accordian folds. The shade was extended to the maximum extension of the 16 3/4-meter-long poles, and the lines were secured. The entire sunshade was then lowered on top of the parasol and clamped in place. The parasol, which had ballooned up at one corner and was not completely covering the Workshop, was extended and flattened out in its desired position when the twin-pole sunshade was placed upon it. The reefing lines on the leading edge of the sunshade were attached to outriggers on the Apollo Telescope Mount structure to spread the shade as much as possible. The shade deployed more as a trapezoid than as a rectangle, primarily because the distance between the outriggers was not quite wide enough to fully extend the leading edge of the sunshade.

Inspections of the command and service module showed that the quads had darkened and were pitted and that the paint between the quads had bubbled and was peeling. The paint had the appearance of a potato chip which was secured to the skin at one edge, but peeling up around the other edges. The diameters of the 10 or 12 chips between each quad were approximately 10 to 15 centimeters.

10.13.2 Second Extravehicular Activity

The second extravehicular activity consisted of the installation of the rate gyro six-pack cable, an Apollo Telescope Mount film exchange, the deployment of two parasol sail samples, and the removal of two more ramps from Apollo Telescope Mount experiment doors. The installation of the rate gyro six-pack cable was time critical, and was accomplished without difficulty and well within the time alloted.

10.13.3 Third Extravehicular Activity

The third extravehicular activity consisted of an Apollo Telescope Mount film exchange, retrieval of one parasol sail sample, and collection of one experiment S230 (Magnetospheric Particle Composition) sample, all of which were accomplished without difficulty. Air cooling, rather than water cooling, was used by all crewmen during the third extravehicular activity. Because the primary coolant loop had failed, leaving only the secondary cooling loop, a decision was made not to put an additional extravehicular activity load on the secondary cooling system. Air cooling for the extravehicular crewmen was acceptable and there was no visor fogging. The absence of water cooling required the work to be performed at a somewhat reduced rate, but the air cooling was adequate for the task at the work rates used.

The crew believes that almost any task that could be accomplished with water cooling during an extravehicular activity could be accomplished with air cooling, but in a slightly longer time period. The third crewman inside the Multiple Docking Adapter was cooled by means of a vacuum cleaner blower connected by a hose to the suit. The air was pulled into rather than blown through the suit with this system. The cooling was adequate only if there was little crewman activity. The air cooling method used during the third extravehicular activity is also discussed in section 8.1.

10.13.4 Post-Extravehicular Activity Operations

Post-extravehicular activity operations were conducted as planned. Hatch closure was not difficult. In opening the airlock compartment after the repressurization, a hot smell of burned paint was always noted. The smell may have been the result of items having been heated by the sun prior to their being transferred into the airlock during the extravehicular activity. Very little moisture was noticed in the suits after each of the extravehicular activities, and the suit drying operations worked well. The dome locker, housing the suit drying blower, had to be left open during periods of blower operation to prevent overheating of the blower.

10.13.5 Summary of Extravehicular Activity

Wrist tethers were used to insure that items for transfer were always tethered to at least one crewman prior to installation in their operational location, except where the Apollo Telescope Mount film canisters were concerned. The location and operation of the foot restraints were satisfactory. Management of the life support umbilical was simple, and the umbilical was never in the way. Extravehicular activity lighting for night operations was good. The installation of the television camera was not difficult; however, the camera has a sensitive aperture adjustment which required very little movement from the fully closed position to provide a properly lighted image. The camera was not pointed at the sun and the ultimate failure was due to the case overheating.

The operation of the extendable booms for transfer of equipment was satisfactory. Had the extendable boom system failed, the ease with which extravehicular activity operations were conducted could have allowed the packages to be manually carried from one location to another, rather than requiring the use of the backup clothesline system. On each extravehicular activity, the sun-end tree would hang up in its stowage location and would require some manipulation to free it.

The experiment S082B (Extreme Ultraviolet Spectroheliograph) door stuck during attempts to open it, and this tendency seemed to worsen as the visit progressed. The door appeared to be sticking at the seal rather than at the hinge.

Physiologically, both of the first extravehicular activity crewmen indicated that, because of the high workload on the hands required to construct the twin-pole sunshade, their finger tips were very sore after the extravehicular activity and remained that way for about a day. Also, a drink bag should be provided for the long extravehicular activities.

Several tasks were accomplished during the extravehicular activities for which little or no preflight training had been received, simply because the need to do these tasks arose during the flight rather than being identified prior to the flight. This experience has shown that, given the proper equipment and instructions and with capable people working out procedures and techniques on the ground, the flight crew could accomplish any reasonable extravehicular activity task. This flight has also shown that any task which could be accomplished in underwater simulations could more easily be accomplished in zero-g. The conduct of extravehicular activity operations in an unhurried, deliberate, and methodical manner contributed significantly to the success of extravehicular activity operations.

10.14 DEACTIVATION

The Orbital Workshop deactivation was performed normally with only a few changes from the originally planned procedures. The following paragraphs discuss some of these changes as well as areas where improvements can be made.

The stowage technique used during the visit was to temporarily stow all items somewhere in the Orbital Workshop after they were used or the requirement had been completed, and then, during deactivation, to restow these items in the command module in accordance with the checklist. A better procedure would have been to restow the items in the command module as they were used, or as the requirements were completed, instead of waiting until the deactivation period.

The transfer of the used film to the stowage location in the command module occurred too early in the deactivation checklist. Thus, had some film not been left unstowed, no film would have been available for photography during the last 2 or 3 days of the visit. A better plan would have been to delay the transfer of film to the command module as long as possible to permit the use of the film as well as permit photography of targets of opportunity.

The deactivation timeline alloted a few hours on the last day of deactivation to review the entry procedures. It would have been better, however, if this activity had been scheduled several days before entry, and had included a touch-the-switch type of walkthrough with the modified checklist that was developed to be used for entry.

A dump of the condensate system was originally scheduled to be accomplished during deactivation. This activity was not performed to insure that the vacuum in the tank would be preserved since it had been very difficult to obtain. In dumping the wardroom water lines into the waste tank, the pressure would rise to the maximum value before the dump was complete. The water dump was supposed to be terminated to permit the pressure in the lines to drop, and then be reinitiated. The pressure in the dump lines would not, however, drop to the value required for dump reinitiation. Consequently, the dump was performed at a higher pressure than desired to complete the total water dump on time.

The inertial measurement unit was powered up and aligned the day before entry rather than on entry day. This was a desirable procedure because last-minute platform alignment problems on entry day were precluded.

For entry day, the plan was to activate only the secondary command module water evaporator while docked. However, when the evaporator was activated, the vehicle was torqued such that the control moment gyros were continuously saturated, requiring the secondary water evaporator to be turned off. Consequently, the primary radiators were then the only means of command module cooling. As a result, after closing the command module hatch, the temperature inside the command module rose to about 302° K and the humidity climbed to a very high level during the 5 to 6 hours prior to undocking. The increase in temperature and humidity in the command module, had a fatiguing and dehydrating effect of the crew prior to entry.

The Multiple Docking Adapter secondary oxygen pack was required to be secured with docking load straps to the Multiple Docking Adapter structure prior to undocking, so that the third visit docking would not cause any movement of the pack. This procedure was followed, but seemed unnecessary, especially since there were many other items in the Workshop which were more loosely tied down than the secondary oxygen pack.

The television camera was mounted on the Apollo Telescope Mount handrail to televise the entry of the third visit crew into the Multiple Docking Adapter.

10.15 ENTRY

On this visit, the sleep cycle was adjusted forward in two 2-hour increments so that the crew would awaken on entry day at approximately the same time that had been normal for the previous several days. Since entry day itself was long, this forced the crew to stay up most of the night, based upon the final clock time that had been established. Actually, there were so many changes that were made to the time of arising, plus several more clock changes to a "pseudo-Zulu" time and then to "phase elapsed time" (adjustment of the clocks to watch the previously scheduled entry timing), that the crew never really knew what time of day was being used without a lot of thought and calculation. Looking back on the flight, the crew believes that it would have been better to remain on G.m.t. and arise at the usual 1100 G.m.t. (6:00 a.m. c.d.t.) for the whole flight. On entry day, since the crew was required to arise 4 hours earlier, they could have simply gone to bed at about 2300 G.m.t. (6:00 p.m. c.d.t.) the night before. An appropriate sleeping capsule could have been taken, and the crew could have arisen 4 hours earlier the next morning. This procedure would have been the most convenient thing from the standpoint of crew rest, and would have avoided confusing the crew timing cycles for the preceeding 6 to 8 days. Also, the recommended procedure might very well have resulted in improved medical data because it would not have been necessary for the crew to try to adjust their circadian rhythm.

Undocking produced a loud thump and imparted a very small velocity to the command module, moving it directly away from the Saturn Workshop. No attitude disturbances were noted during this phase. After the range to the Saturn Workshop was over 30 meters, attitude maneuvers were initiated in the docked digital autopilot mode with excellent results. The spacecraft was then maneuvered using the undocked digital autopilot and the stabilization and control system over the next several minutes. The command and service module was controllable in all modes with the docked digital autopilot exhibiting the best overall characteristics because of its lack of apparent crosscoupling. The maneuver to the firing attitude was performed manually, again using the docked digital autopilot configuration.

Approximately 30 minutes prior to the deorbit maneuver, the Scientist Pilot took a Scopolamine/Dextroamphetamine capsule to inhibit motion sickness after landing. The Commander and Pilot took the same medication approximately 3 minutes after command module/service module separation to minimize any lightheaded effects. Approximately 10 minutes prior to the deorbit maneuver, all three crewmen inflated their orthostatic counter measure garments to 175 mm Hg pressure to minimize the possibility of reduced vision or reduced mental acuity during the firing. However, it was later found that the Scientist Pilot's garment would not hold pressure. He noted no unusual effects, however, even without the assistance of the counter-pressure.

The entry batteries did not assume much of the electrical load when placed on line just prior to the deorbit maneuver. The low current output was caused by low battery voltages (31 to 32 volts), about the same as the descent batteries. To ascertain if the entry batteries were on the line, descent battery 2 was disconnected. This lowered the main bus voltage showing that the entry batteries were on the line but not fully charged. The situation was rather uncomfortable as there was no positive assurance that the entry batteries could support the command module loads with the approaching command module/service module separation time. The crew would have had a more comfortable feeling about entry had the batteries been charged to their peak voltage prior to entry.

Holding the desired attitude during the ullage maneuver prior to the deorbit maneuver was not easy in the undocked digital autopilot mode because of the two quads being disabled. Yaw excursions had to be nulled using the translation controller with a technique suggested in the deorbit maneuver study guide that had been sent up a week or so prior to entry. Without the benefit of the study guide information, holding attitudes during the ullage maneuver would have been much more difficult. The deorbit maneuver ignition occurred on time and appeared to produce a smaller start transient than the rendezvous firings. None of the crewmen felt a tendency to gray out. Vision was not restricted nor was any degradation in the ability to concentrate noted. The crew believes that inflation of the orthostatic counter measure garments did not contribute significantly to preventing blood flow from the head.

10.15. Command Module/Service Module Separation

After completion of the deorbit maneuver, the X-axis residual was trimmed. The command module was yawed right 0.76 radian and quads B and D were activated. No observable change in attitude or rates was noticed at this time; however, at command module/service module separation, the command module did develop a slow right yaw. The yaw excursion was arrested using the direct switches and, as the command module was maneuvered back to the orbit plane, the docking ring was jettisoned. Section 7.6 contains a discussion of the yaw excursion encountered during the separation sequence. The docking ring and probe were observed departing the spacecraft at a relatively rapid rate.

10.15.2 Entry

Ample time was available to configure the computer, make last minute adjustments to restraints, and maneuver the spacecraft to the entry attitude. The horizon check was completed satisfactorily as were the 0.05g checks. Approximately 5 to 10 seconds prior to 0.5g ionization of

the atmosphere around the spacecraft was observed as a yellow-gold or peach-colored hue superimposed on the blackness of space. The peach hue was not observable against the earth for the first 10 to 15 seconds. Then, finally, the entire scene outside the spacecraft became covered in this hue. Shortly thereafter, the glow moved aft and formed a very bright ball about 15 to 20 meters aft of the spacecraft and seemed to be fed by 2 or 3 spiral arms of bright fire emanating from the command module heat shield area. The fireball appeared to move about as a result of thruster firing. The cockpit displays were difficult to see for 5 to 10 seconds after looking at the bright ball behind the spacecraft for even a few seconds.

At about this point, the g forces were sensed to be building up. At the 0.2g check, all parameters were normal so spacecraft control was transferred to the command module computer for the remainder of the entry. The crew continued to monitor the displays to insure that the spacecraft responded to command module computer commmands and that the command module computer commands were proper. Both the initial command module computer commanded bank angle direction and the time to reverse bank were exactly as predicted on the entry computations.

At no time during the entry did any of the crewmembers have a tendency to gray out or experience problems with mental alertness. Discomfort was experienced because a metal snap on the back of the orthostatic counter measure garment and its mating snap on the back of the jacket were both being pressed into the lower back area.

Drogue parachute deployment occurred near the predicted time and at the proper altitude as indicated on the altimeter. The time did not compare with the differential time for drogue deployment computed by the Pilot using the primary evaporator pressure indications, which suggested that drogue deployment should have occurred some 15 to 20 seconds earlier. Main parachute deployment (fig. 10-17) was normal. Communication with the recovery forces was well disciplined in that the only conversation between the spacecraft and the helicopter was a request for latitude and longitude and the entry monitor system miss distance. An improvement would be notification by the helicopter pilot when the spacecraft is within 20 to 30 seconds of landing. Water impact was moderate and the command module immediately went to the stable II attitude. The parachutes were jettisoned and were observed floating nearby. The postlanding checklist was performed and uprighting occurred some 10 minutes later.

Immediately after uprighting, an attempt was made to contact the recover forces on the radio with no success. The crew learned later that the Commander and Pilot communication systems were in the "hot mike" mode continuously because sea water had shorted some pins on an unprotected connector in the command module tunnel area. This problem is discussed further in section 7.4.

Figure 10-17.- Main parachute deployment.

Postlanding verification was initiated by first pulling the postlanding ventilation valve, turning on the fan switch, and then pushing in the circuit breaker. As the circuit breaker was depressed, a small spray of water and a mild cabin recompression or decompression occurred, producing a brief "fog" within the cockpit. The pressure change was not expected. Section 7.8 contains a discussion of this problem.

During the time on the water, both in stable II and stable I attitudes, the crew felt no seasickness symptoms or any other motion sensitivity abnormality. The crew felt well even though the waves and swells were unusually high and the frogmen appeared to be having a difficult time attempting to attach the flotation collar.

The first indication of any unusual motion sensitivity occurred when the spacecraft had been hoisted from the water and was steady on the deck of the recovery ship. Once the spacecraft came to rest and remained there for 1 or 2 minutes, erroneous attitude signals could be excited simply by moving one's head. The crew believes that this was not a motion sickness symptom, but rather an indication of an erroneous vestibular output.

Once on the ship, the planned postlanding blood pressure measuring procedures could not be performed, because the spacecraft's onboard blood pressure cuff would not hold pressure. Postflight evaluation showed that a small ball that fits beneath the pressure relief nut had floated away when the nut had come loose several weeks prior to landing. Because of the cuff failure, blood pressure measurements on each crewman were accomplished after the hatch was open, thus delaying the exit from the spacecraft.

The procedure that was used, whereby the crewmen (after egressing the cabin) moved only a very short distance and were accompanied by two flight surgeons, was an excellent one and should be used for the next visit. The help was not unduly restricting, and decreased the possibility of falling or fainting.

The orthostatic counter measure garment on the Commander and the Pilot maintained 175 mm Hg inflation during this period. The Scientist Pilot's garment would not hold full pressure because of leakage, but remained at a pressure of about 40 to 50 mm Hg. The garment proved to be helpful in preventing blood from pooling in the legs for at least 4 to 5 hours after landing.

10.16 POSTFLIGHT

The postflight protocol was well organized, smoothly executed, but made the landing day too long. The time from crew wakeup in orbit through deactivation of the Workshop, checkout of the command module, undocking, entry, recovery, and postflight medical checks resulted in each crewman being awake approximately 26 continuous hours. This was tiring and must have affected some of the medical data, perhaps the M171 (Metabolic Activity) experiment. On the other hand, the desirability of taking medical data as soon as possible after landing to observe the changes taking place during this dynamic period is understood. Three potential improvement areas exist that should be investigated to decrease the total length of time that the crew must be awake. These are: reduce the time required to deactivate the Saturn Workshop on entry day by closing out some of the Workshop systems the day before entry; reduce the time required for the command module checkout and power-up procedures on entry day by the same method; and make a detailed evaluation of the recovery day medical protocol to determine which tests must be conducted immediately after landing and those that could slip to the next day. Experiment M078 (Bone Mineral Measurement) might well be delayed as bone density does not appear to change rapidly. A final point is the desirability of providing a fairly early meal to the crew on the day of landing as it will very likely be a good many hours past their normal dinner time by the time they are recovered, and consistent with the tests to be given, a substantial meal other than a simple snack should be provided.

The physical examinations on the first and second day after recovery (prior to leaving the ship and returning to Houston) were well planned. The work schedule was not tiring and ample time was available for rest. Although mild, the rolling and pitching of the recovery ship at sea was disturbing to the crew when undergoing tests and may have compromised some data. A significant improvement in the subjective feeling was noted once the ship tied up at the pier; however, one could still get an impression of the ship moving simply by moving one's head.

The total time spent on the ship after recovery and prior to returning to Houston was not excessive. In fact, it was generally felt that at least two full days are desirable prior to return.

Activities after returning to Houston were too hectic. Immediately beginning a series of debriefings did not allow the crew to rest adequately and get some of their preflight strength back. Although this may have been necessary for this flight because of third visit considerations, the necessity does not exist after the final visit. A desirable situation would be to allow the crewmen about a week of leave immediately after their return, during which the crew would rest and perform only the necessary medical tests prior to beginning their debriefing. Also, this would provide additional time for some of the flight data such as movies and still photographs to be developed and used during the debriefings.

10.17 TRAINING

10.17.1 Summary

Training for the second visit went well. By launch day, each member of the crew had averaged about 2800 hours of training time with [illegible]30 hours spent in the command module simulator and 345 hours spent in the Skylab simulator. The total training time was more than had been accumulated by any other crew since the beginning of manned space flight. The training appeared to pay off in flight as no crewman could remember a scheduled task for which he had not been trained. In a few cases, however, so much time had elapsed since training that some of the details had been forgotten, but the crewman at least had the background for performing the task properly.

Too many training hours were devoted to learning skills that were not used in flight. One example of this was the many hours spent for inflight medical support system medical training by the Commander and Pilot wherein rapid crew response was not required. This comment does not apply to emergency first aid training which must be learned and known well. In most illnesses, an instantaneous reaction is not too important. The inflight medical support system checklist, plus discussions with the ground, would have allowed a crewman with minimal training to perform almost as well as a crewman with much training.

Conversely, there were some skills that were used every day of the flight, but, because the task was easy, had been practiced infrequently. An example is the postsleep and presleep procedures. These procedures were performed every day and added up to a significant amount of flight time that, had the crew been trained to perform more efficiently, would have resulted in a significant time savings.

Perhaps the major area of insufficient training was in earth observations and photography. Essentially all of the limited preflight training in this area was initiated by the crew, yet numerous tasks were assigned in flight that required identification and photography of special features of interest. Additional training time should have been spent in understanding the objectives relating to geology, geography, meteorology, hydrology, fishing, etc.

The preflight training schedule was revised weekly. This resulted from the fact that all training needs could not be predicted early in the program, and also from the identification of new training areas as the mission preparation progressed. Experience during the preflight period indicated that the best training protocol was a mixture of what the crew thought was needed and what the training coordinators and training instructors believed the crew needed. Overtraining in some areas resulted from satisfying both groups, but no weakness was overlooked.

10.17.2 Inflight Training

The increased visit duration of Skylab has enabled modifications to the inflight operations to take advantage of actual occurrences and learning. Because of this new capability, flight time should be scheduled for required retraining. In one instance, time was allotted to review and practice the entry procedures, which had been modified significantly, and this time paid off on entry day. Many inflight modifications were made to Apollo Telescope Mount operations, yet time was never allotted for what could be considered a training session. It would be helpful to set aside some time every week or two for the crew to read and practice ground-uplinked study guides to learn, in a systematic manner, the changes in Apollo Telescope Mount operation. The technique for implementing this idea needs further definition, but is one that would produce improved experiment results. When crew time is at a very high premium, as it was on the second visit, it may be necessary to train and attempt to complete scientific objectives simultaneously, but the primary goal should be training.

10.17.3 Command Module Simulator

The command module simulator training was excellent. An inordinate amount of down time occurred during the training period, particularly at the beginning of the mission simulations. Some of the down time was the result of hardware age; however, some was also caused by the decrease in manpower available to maintain the simulators. The simulator, however, did perform when it was absolutely required.

One constant simulator deficiency was that the out-the-window displays were not kept in adjustment as evidenced by the fact that the displays were adjusted prior to an entry simulation and were very good. Prior to that time, the out-the-window cues were not particularly helpful in verifying firing attitudes, entry attitudes, and backup flying techniques. One of the main difficulties was that, during the night phase of the orbit, the occulting disc appeared difficult to adjust and was barely visible within the lighted cockpit. Experience has shown that the training was of much more value when the lighted horizon was kept on at all times. This change allowed the crew to practice both day and night procedures and halved the adjustment problems for the maintenance personnel.

The adjustable sound cues in the command module simulator provided an extremely useful reference. Repeated during orbit, the crewmen differed in their opinions of sounds just heard, and since any single setting of a simulator sound will probably not be satisfactory, the variety of sounds that can be heard for the same event throughout the training cycle teaches a crewman to be alert to all frequencies and sound levels.

The crew found it useful to practice stowage and unstowage during the rendezvous and entry simulations late in the training cycle. However, only those items that would be handled during these time-critical mission phases were required for stowage in the command module simulator.

10.17.4 Skylab Simulator

The Skylab simulator was a valuable tool in learning the Saturn Workshop operating systems. The simulator was used more in learning to operate the Apollo Telescope Mount and in understanding the attitude control system than it was in learning to operate the environmental control system or the electrical power system. This resulted from the fact that the crew was not required to know all details of the latter systems because the ground monitored the systems completely and the crew interface was mostly one of verifying the proper gage reading or in making some requested control adjustment. For the environmental control and electrical systems, understanding only the time-critical failures would have been a reasonable goal.

An extremely useful capability was introduced into this simulator late in the training cycle. It allowed one crewman to fly the attitude control system and associated controls and displays while the other crewman operated the other Workshop systems and the Apollo Telescope Mount. This enabled training in attitude control system failures and maneuvers (runaway thrusters, control moment gyro failures, and manual maneuvers) while maintaining Apollo Telescope Mount pointing at the sun. The dual operations capability increased the usefulness of the simulator and is an applicable principle for future simulators.

The fact that the Skylab simulator was not designed to resemble the vehicle but, rather, was essentially a room with the appropriate control and display panels mounted randomly was no hinderance. However, the need for all of the controls and displays that require manipulation in flight to be exactly duplicated somewhere in the simulator cannot be overstressed. This is particularly important for valves and hatches that are used to control the cabin pressure.

A major drawback of the Skylab simulator, in comparison with the command module simulator, was the lack of suitable displays to provide the instructors with rapid and accurate indications of the operations being performed inside the simulator. The lack of adequate indications of crew operations often resulted in degraded training.

10.17.5 Command Module Procedures Simulator

The command module procedures simulator was an excellent tool for rendezvous and entry procedures training. The inherent rapid-reset provisions under a variety of initial conditions made part-task training efficient. Also, the dual capability of having the instructor inside the simulator with the trainee or outside the simulator at the console was good.

10.17.6 Orbital Workshop and Multiple Docking Adapter One-g Trainer

The Orbital Workshop one-g trainer was an excellent training tool and the high fidelity and accurate stowage capability enabled the crew to perform efficently. This trainer provided the only way to develop certain procedures and, therefore, enabled the crew to reach a level of competence prior to flight that could not have been attained by other means. An important item for future consideration is that the high fidelity equipment should be maintained in its operational use position rather than in the launch or in-orbit stowage position.

10.17.7 Command Module One-g Trainer

The command module one-g trainer was used extensively for launch and entry stowage and for familiarization with the docking probe and drogue. The probe and drogue operations were best learned in this simulator. However, the stowage training is a different matter. On the relatively long and complicated Skylab flights, the actual launch stowage was not finalized until several days prior to flight, and the entry stowage was not finalized until just prior to entry. A significant amount of crew time was spent in this trainer optimizing launch stowage and in learning to stow for entry, but relearning was required when the time came to actually perform stowage operations. Based on the second visit experience, the crew believes that it would be appropriate to work on the stowage only during the development phases of the program and, once that operation is complete, the crew should almost completely ignore stowage until a week or less before flight. At that time, a general run-through of the launch and entry stowage would be all that is needed.

10.17.8 Neutral Buoyancy Trainer

The neutral buoyancy trainer was an effective training device. This device developed the skills needed for extravehicular activity and they were developed rapidly and with confidence. Experience on this visit also showed that once basic extravehicular activity skills are acquired in the

water tank, a crewman can perform extravehicular activity tasks for which he is not specifically trained if adequately detailed instructions are given. The techniques and skills developed underwater are almost identical to those used during the extravehicular activity, with the actual zero-g task being slightly easier.

The use of full-scale mockups for underwater extravehicular activity practice is mandatory. Sections of the vehicle should not be deleted unless the extravehicular activity crewman is not to work at that section or not to travel over the section.

Underwater simulations and training are not needed for intravehicular activity tasks unless a crewman is to be operating in a pressurized suit. Anything that can be done on earth in one-g in shirtsleeves can be accomplished in zero-g. A slightly different body positioning may be required in zero-g; however, this can be thought through with relative ease in a high fidelity one-g trainer. Even intravehicular activity tasks with such hardware as maneuvering units and the movement of large packages need not be simulated in an underwater environment.

10.17.9 Earth Resources Experiment Package Simulator

The Earth Resources Experiment Package simulator, composed of a viewfinder tracking system and control and display panels, was an excellent training tool. The control and display simulator was a simple device because the inflight crew task was mostly one of switch positioning, with little decision making required. The viewfinder tracking system simulator was necessarily more complex because it required pointing and tracking of a specific point on the earth's surface.

The two second-visit crewmen who trained on the viewfinder tracking system believe that site recognition is easier in the simulator because the haze that obscured many inflight targets was more severe than simulated. The ability to introduce haze levels from zero percent in the early levels of training to near 100 percent during the advanced training would be a desirable simulation technique. Also, the Earth Resources Technology Satellite earth infrared photographs used in the viewfinder tracking system simulator were not satisfactory in that the earth just does not look like the infrared photographs from the Skylab orbital altitude. It would be much better to use any other available photography, even those taken from orbit with hand-held cameras.

There was pronounced inflight learning over and above the training received on the viewfinder tracking system. After one or two Earth Resources Experiment Package passes, a crewman becomes confident that a site can be found, if it is visible at all. This was induced largely by an increased understanding of the field of view visible through the flight viewfinder tracking system and the improved study techniques of onboard maps and charts just prior to the pass.

10.17.10 Command Module Simulator/Skylab Simulator One-g Trainer Simulations

The simulations conducted simultaneously with the command module simulator and the Skylab simulator were an essential part of training. These simulations provided the means to join together all the different mission and experiment skills that were learned up to that point. These simulations should be conducted relatively early in the training cycle to allow the crew a better appreciation of the total task, even though high fidelity equipment may not be available. This training is the best place to gain familiarity with flight plans, teleprinter pads, checklists, and their interrelation and flow. Working the overall daily flight plan, moving from experiment to experiment, is greatly different than working a couple of hours on an experiment with the instructor. The simulations should be as flight-like as possible, although introducing system failures does not appear to be desirable. Every type of daily activity should be introduced during the simulations, including experiments, recording, simulated debriefing, waste management, crew exercise, and crew entertainment, so that complete days are simulated.

10.17.11 Simulated Network Simulations

The simulated network simulations employing vehicle simulators, trainers, and the mission control center are the best overall training tool available. These simulations join the mission for the crew and all of the flight controllers. Continued simulations of normal inflight operations did not appear necessary once teleprinter formats were understood. The more important areas to simulate were the dynamics phases, including launch, rendezvous, deactivation, and entry, where time critical coordination was required.

10.17.12 Air Bearing Training

The air bearing trainer did not provide very useful training for either experiment M509 or T020. The limited degrees of freedom inherent in the trainer constrain the crewman from learning to fly the maneuvering units. The maneuvering skills were much better learned on the 6-degree-of-freedom simulator. The air bearing trainer did provide limited training in procedures. A combination of a 6-degree-of-freedom simulator plus procedures walk-through in the one-g trainer would teach all of the necessary inflight skills, and as indicated in section 10.11.1, an air bearing training will not teach the necessary skills.

10.17.13 Extravehicular Mobility Unit Altitude Chamber Training

The extravehicular mobility unit altitude chamber exercisers were excellent training, particularly for crewmen who are not experienced with extravehicular activity equipment. This training was a great confidence builder as well as providing the only opportunity to operate the flight equipment under both nominal and off-nominal conditions.

The pressure suits fit all crewmen well during flight and this resulted from two preflight procedures. First, the flight and backup suit were worn several times during training. Stretching the suit in training, then adjusting the suits to fit again, eliminated suit growth in flight. Second, the flight suits were fit checked on the evening prior to launch. All crewmen donned their flight suits, complete with all launch flight equipment such as biomedical amplifier and constant wear garment, for final adjustment. When this fit check was completed, the suit was removed, reconfigured for extravehicular activity, and tried on again. As a result, several small problems were disclosed and fixed prior to launch.

10.17.14 Hand-Held Photography and Television Training

Hand-held photography and television training was probably one of the weaker training areas. Sufficient time was not spent inside the simulator taking pictures of another crewman or taking pictures of simulated targets out the window. Also, the printed pictures that were taken were not seen by the crew nor were any suggestions for improvement received. Configuring the trainer with both the interior and exterior cameras and devoting several hours during training to taking pictures would have been advantageous. Instead, the crew devoted most of the photography training sessions to general briefings on cameras and malfunction procedures. The crew would have been better trained if the malfunction procedures had been de-emphasized and supervised photographic and television cameras operation emphasized.

10.17.15 Inflight Fire and Rapid Differential Pressure Drill

An inflight fire and a rapid-loss-of-differential-pressure drill was performed during the first few days of the visit. The drill was good training and is recommended for future crews. The natural way a crewman stands relative to hatches and valves in the one-g trainers is often different from the floating positions inflight and, as a result, the crewman may be somewhat confused regarding relative position the first time the exercise is performed. Also, the optimum location for cue cards may change. Because of the many variables between ground training and flight conditions, the first inflight exercise is required to reveal potential problems.

11.0 GENERAL PHOTOGRAPHY AND CAMERA SYSTEMS

11.1 SUMMARY

The general photographic systems included 35-mm and 70-mm still cameras, 16-mm sequential cameras, a 127-mm earth terrain camera, and a Polaroid SX-70 camera. These systems were used to provide data and documentation of the following areas:

a. Exterior configuration of the Orbital Workshop prior to docking and after undocking

b. Docking dynamics of the command and service module

c. General Orbital Workshop operations

d. Crew-option photography of earth areas of interest in accordance with premission briefings

e. Specific earth areas in support of the Earth Resources Experiment Package operations

f. Various experiments data scheduled for this visit

g. Anomalous conditions

h. Closeout configuration of the Orbital Workshop

i. Extravehicular and intravehicular crew activities

The basic descriptions of those photographic systems used for the first time in the Skylab Program are contained in Appendix A of this report with further details contained in reference 5. The systems were basically the same as those used on the first visit, with the exception of additional 35-mm equipment in support of experiment S063 (Ultraviolet and Visible Earth Photography) and the addition of haze filters for ground photography.

More extensive use was made of the general photographic systems during the second visit for earth observations. The supply of film was adequate to meet all requirements, but tight film budgeting was required, and very little film remained for optional crew photography.

11.2 DATA ACQUISITION CAMERA (16-mm) SYSTEM

The 16-mm data acquisition camera system was used to record the exterior and interior of the Saturn Workshop, the extravehicular and intravehicular crew activities, and in support of many experiments.

Table 11-I lists the 16-mm camera usage for this visit. The planned T027/S073 (Contamination Measurement/Gegenschein Zodiacal Light) photography was not accomplished because the experiment was jettisoned; however, one of the remaining two rolls of film for this experiment was used for miscellaneous targets. Two of the three magazines were used as planned in the command module, and the other was used for additional experiment S191 (Infrared Spectrometer) photography.

Interior workshop and command module photography and experiment photography was satisfactory. Over 5000 meters of film were used in documenting crew operations and experiment activities. Radiation fogging of film that was launched on the Orbital Workshop was apparent on some of the film.

Equipment performance was satisfactory. The same procedures used during the first visit for clearing the thermally degraded film from the 16-mm film canisters were again used on the second visit. One film jam occurred on the 16-mm system, but was cleared using the onboard procedures. One fuse blew for some unknown reason and was replaced.

The camera used at the film threading station had erratic end of film light indications. Therefore, the camera was replaced. Analysis indicates that the bellows interface between the camera and the film transporter failed. See section 17.3.6 for a discussion of this anomaly.

Nine of the eleven 16-mm cameras on board were used for an approximate total operating time of 41 hours, and one camera was jettisoned with a malfunctioned experiment. Four of the six first-visit surplus 122-meter canisters and three of the third visit canisters were used. One unused roll of 122-meter film was returned for analysis of radiation fogging.

11.3 35-mm CAMERA SYSTEM

The 35-mm camera system was used as planned (see table 11-II) to record data for experiment S063 (Ultraviolet Airglow Horizon Photography), student experiments, and closeout and operational photography. As in the first visit, the crew used the 300-mm lens for air-to-ground photography of targets of interest.

TABLE 11-I.- PLANNED 16-mm CAMERA USAGE

Experiment/ activity	Experiment/Activity Title
D021	Expandable airlock
ED52	Spider web formation
ED72	Capillary studies
ED74	Mass measurement
ED78	Liquid motion
M092	Lower body negative pressure
M093	Vectorcardiogram
M110	Blood sampling
M131	Human vestibular function
M151	Time and motion study
M171	Metabolic activity
M479	Zero gravity flammability
M487	Habitability/crew quarters
M509	Astronaut maneuvering equipment
M512	Materials processing in space
M516	Crew activities/maintenance study
S019	Ultraviolet stellar astronomy
S020	X-Ray ultraviolet solar photography
S149	Particle collection
S183	Ultraviolet panorama
S191	Earth Resources Experiment Package - infrared spectrometer
T013	Crew vehicle distrubances
T020	Foot controlled maneuvering unit
EVA	Extravehicular activity
Operational	Flyaround activity, vehicle inspection, and interior crew activities

TABLE 11-II.- FILM UTILIZATION WITH 35-mm CAMERA

Magazine[a]	Film type	Frames used	Activity
CI99	S0168	59	Student experiment
CI100	S0168	66	Student experiment and general interior
CI101	S0168	61	General interior
CI102	S0168	67	General interior
CI103	S0168	62	General interior
CI104	S0168	60	Experiment S063
CI105	S0168	66	Student experiment and general interior
CI106	S0168	52	General interior
CI107	S0168	31	Interior closeout
CX12	S0368	63	Earth looking
CX13	S0368	63	Earth looking
CX24	S0368		Experiment S063 calibration
CX28	S0368	47	Extravehicular activity and earth looking
CX29	S0368	68	Earth looking
CX30	S0368	65	Earth looking
CX31	S0368	60	Earth looking
CX32	S0368	63	Earth looking
CX33	S0368	71	Earth looking
CX34	S0368	71	Earth looking
CX35	S0368	68	Extravehicular activity and earth looking
BV13	2485	40	Experiment S063
BV14	2485	40	Experiment S063
BV15	2485	40	Experiment S063
BV16	2485	40	Experiment S063
BW07	3400	Not used (left in Orbital Workshop)	

[a]The magazine prefix CI indicates interior color film with an ASA rating of 500, CX indicates exterior color film with an ASA rating of 64, BV indicates high-speed black and white film with an ASA rating of 4000, and BW indicates black and white film with an ASA rating of [illegible].

The 35-mm manual camera system operated satisfactorily. The 35-mm electric camera system operation was satisfactory, except that the camera cycled in the continuous mode when initiated by the experiment S063 variable exposure timer. This condition occurred on two separate occasions and each time, 10 to 15 frames of film were wasted. The variable exposure timer is a precision timer with a 3-position mode selection switch. The most likely cause of the cycling was that the mode selector switch was in an incorrect position. The crew confirmed that this could have occurred. One variable exposure timer was inadvertently left on and the battery energy was depleted.

Flight film results indicate that the system functioned as expected. The electronic flash greatly enhanced the interior photography. Figure 11-1 is a typical picture of the interior operational documentation photography obtained using the electronic flash unit. The 300-mm lens on the 35-mm camera contributed to the air-to-ground photography of targets of opportunity; however, camera motion and overexposure degraded some photography. Figure 11-2 is a typical picture of extravehicular activity documentation from the area of the hatch.

11.4 DATA CAMERA SYSTEM

The 70-mm data camera system was used for operational photography of the Saturn Workshop exterior during approach and docking. General and scientific interest photographs of the earth were taken of active volcanoes, tropical storms, and Mexican earthquake damage. After visit day 26, the crew was given specific areas for synoptic photography. These included the Great Barrier Reef, sea state area around Typhoon Iris, Antipodes Islands, Straits of Magellan, Patagonia Desert, and the Lagoa Freitas Lagoon.

The data camera system with the 100-mm lens was used for the majority of the earth looking photography, and the 80-mm lens was used for vehicle photography.

Figure 11-1.- Typical interior documentation with electronic flash.

Figure 11-2.- Typical extravehicular activity documentation photograph.

The following table shows the system usage for the second visit.

Magazine[a]	Frames used	Earth views	Vehicle views
CX10	148	63	85
CX11	137	137	-
CX25	153	134	19
CX26	157	157	-
CX27	158	151	1

[a]CX designation preceding magazine number indicates color exterior film.

The typical 70-mm photographic data are shown in figures 11-3, 11-4, and 11-5. Figure 11-3 shows the Orbital Workshop as the command and service module was approaching for docking. Figure 11-4 was taken of the earth, using the 100-mm lens. Figure 11-5 shows the reefed main parachutes and was taken during the landing sequence with the 80-mm lens.

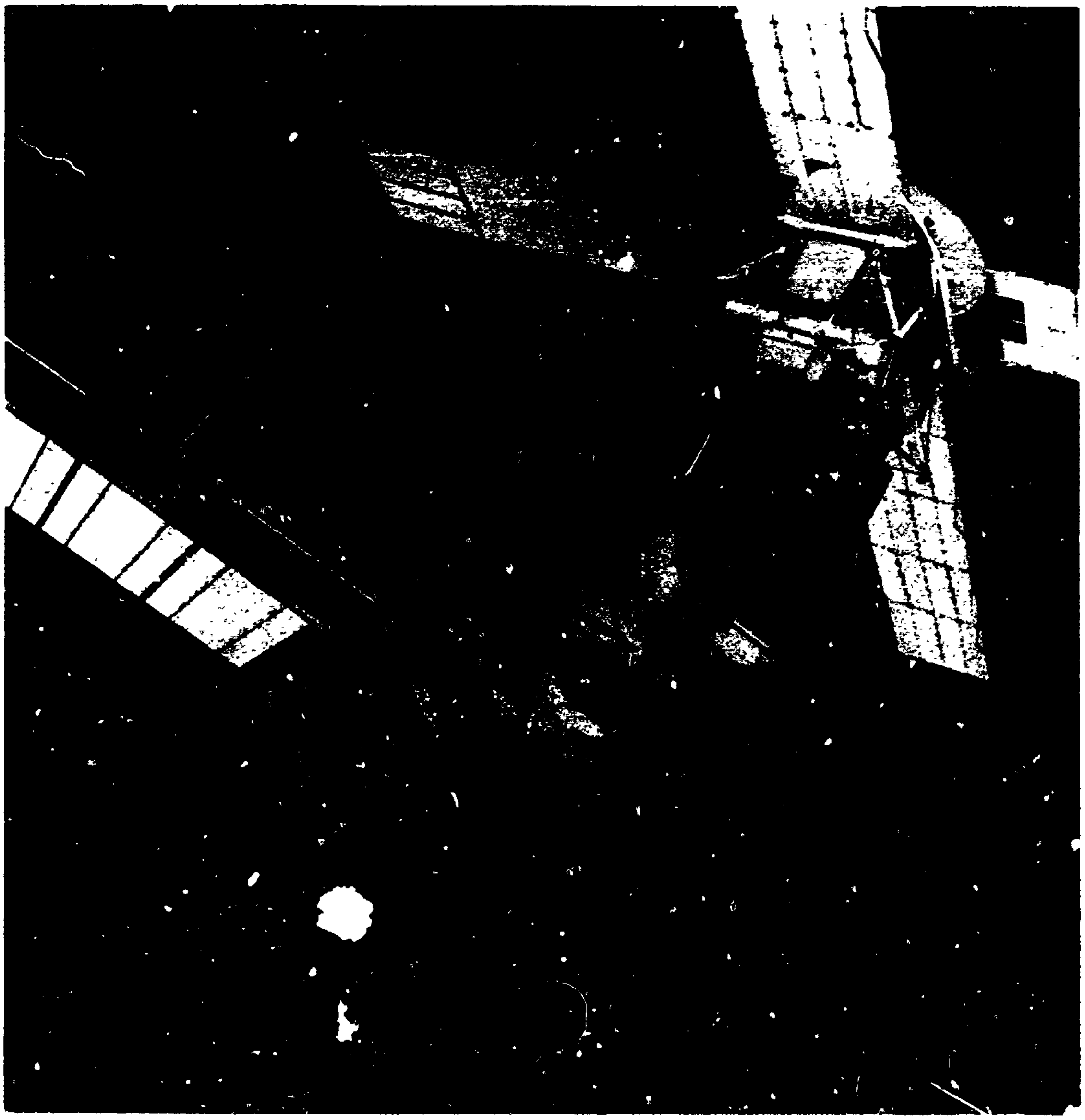


Figure 11-3.- Photograph of Orbital Workshop taken from command module during docking sequence with 80 mm lens.

Figure 11-4.- Typical Earth view photograph taken from Orbital Workshop with 100 mm lens.

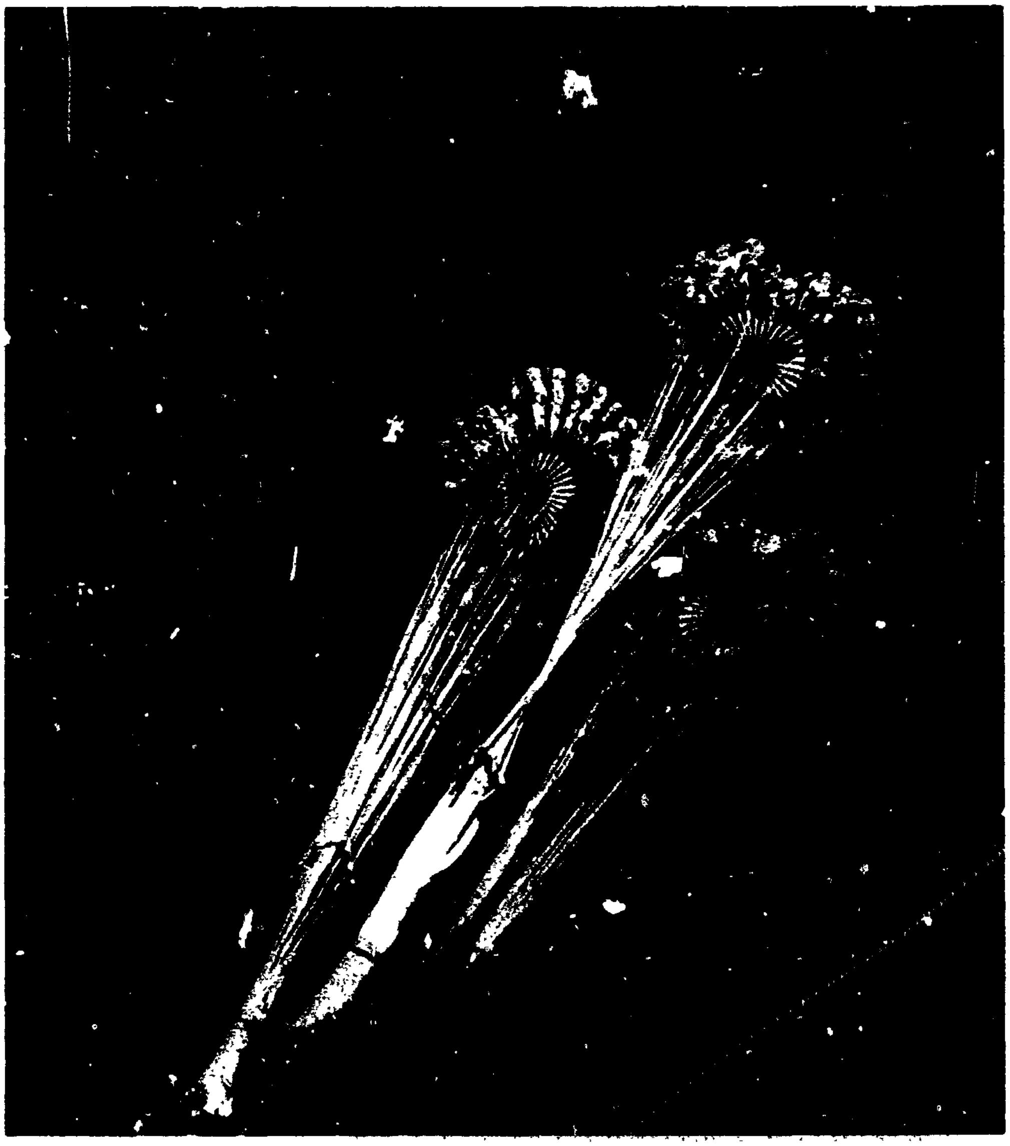


Figure 11-5.- Photograph of reefed main parachutes taken during entry sequence.

12.0 TRAJECTORY

Lift-off occurred at 11:10:50.5 G.m.t. (7:10:50.5 a.m. e.d.t.) on July 28, 1973, (visit day 1) from launch complex 39B. Orbital insertion occurred 10 minutes and 2.5 seconds later with a 154.7 by 231.2 kilometer orbit achieved. A nominal five-orbit rendezvous was flown with docking at 8 hours 21 minutes (19:32 G.m.t.) after lift-off.

The rendezvous maneuvers (table 12-I) were well executed and the maneuver solution sources agreed within the comparison limits. Three items of concern were noted.

a. The iterative solutions for the terminal phase initiation maneuver differed more than expected.

b. The change in execution time of the terminal phase initiation maneuver was greater than expected.

c. The solution for the second midcourse correction of 3.05 meters per second was larger than expected.

Analysis indicates that an unmodeled integration error may have caused each of these deviations and they could recur. The loss of one reaction control system quad caused some minor problems during the braking phase of the rendezvous. The reduced control authority increased the difficulty in controlling the line-of-sight rates primarily in the vertical direction.

Orbital trim maneuvers of the Saturn Workshop/command and service module were not performed because of the reaction control system problem. The orbit was allowed to decay naturally and, as a result, the drift rate of the ground track in an easterly direction increased. The two effects of this drift rate are that the ground track no longer repeats every five days, and the rendezvous-during-the-fifth-orbit launch opportunity for the next visit will occur approximately 2 minutes earlier each five days.

A summary of the Earth Resources Experiment Package data passes is presented in table 12-II and figure 12-1.

The second visit deorbit plan was modified because of the reaction control system problem. The premission deorbit plan required two service propulsion maneuvers. A backup deorbit plan using two reaction control system maneuvers retained the capability to land the spacecraft on the same revolution as the primary deorbit plan. The modification substituted a single service propulsion system deorbit maneuver with the spacecraft descending along the west coast to a landing near San Diego, California.

TABLE 12-I.- RENDEZVOUS MANEUVER SUMMARY

Event	Preflight profile			Real time profile		
	G.m.t., hr:min:sec	Elapsed time, hr:min:sec	Differential velocity meters/sec	G.m.t., hr:min:sec	Elapsed time, hr:min:sec	Differential velocity, meters/sec
First phasing maneuver	13:26:19	2:17:29	67.39	13:28:56	2:18:06	65.44
Second phasing maneuver	15:42:13	4:33:23	48.15	15:44:45	4:33:54	47.57
Corrective combination maneuver	16:28:22	5:19:32	9.02	16:30:53	5:20:03	11.46
Coelliptic maneuver	17:05:22	5:56:32	5.85	17:07:53	5:57:03	6.40
Terminal phase initiation	18:21:12	7:12:22	6.37	18:27:26	7:17:36	6.49
Terminal phase finalization	18:54:54	7:46:04	8.32	19:01:14	7:50:24	--
Docking	19:38:50	8:30:00	--	19:32:00	8:21:10	--

TABLE 12-II.- EARTH RESOURCES EXPERIMENT PACKAGE PASS SUMMARY

Pass	Track	Revolution	Visit day	Data taking period, min	Longitude, deg	
					Start	Stop
1	34	1170/1171	7	33	152 W	46 W
2	48	1184	8	40	173 E	50 W
3	61	1197	9	14	125 W	58 W
4	62	1198	9	29	128 W	41 W
5	34	1241/1242	12	35	167 W	48 W
6	47	1254/1255	13	19	108 W	40 W
7	6	1284	15	19	128 W	74 W
8	13	1291	15[a]	27	91 E	167 E
9	20	1298	16[b]	24	120 W	55 W
10	25/26	1587/1588	36	22	102 W	24
11	39/40	1602	37	35	76 W	—
12	41	1604	37	5	62 W	50 W
13	54/55	1616/1617	38	35	75 W	18 E
14	68/69	1630/1631	39	31	65 W	14 E
15	70	1633	39	3	75 W	54 W
16	30	1663	41	15	128 W	77 W
17	44	1677	42	16	127 W	67 W
18	1	1705	44	30	129 W	30 W
19	15	1719	45	21	117 W	38 W
20	16	1720	45	17	132 W	63 W
21	26/27	1731	46	13	31 W	15 E
22			Cancelled			
23	31	1735	46[b]	10	127 W	75 W
24	41	1745	47	12	23 W	17 E
25	43	1747	47	25	123 W	53 W
26	45	1749	47	18	158 W	79 W
27	58	1762	48	20	115 W	27 W
28	59	1763	48	26	137 W	21 W
29	1	1776/1777	49	27	126 W	18 W
30			Cancelled			
31	15	1790/1791	50	29	123 W	8 W

[a]Earth's limb data also taken on this day.

[b]Lunar calibration data also taken on this day.

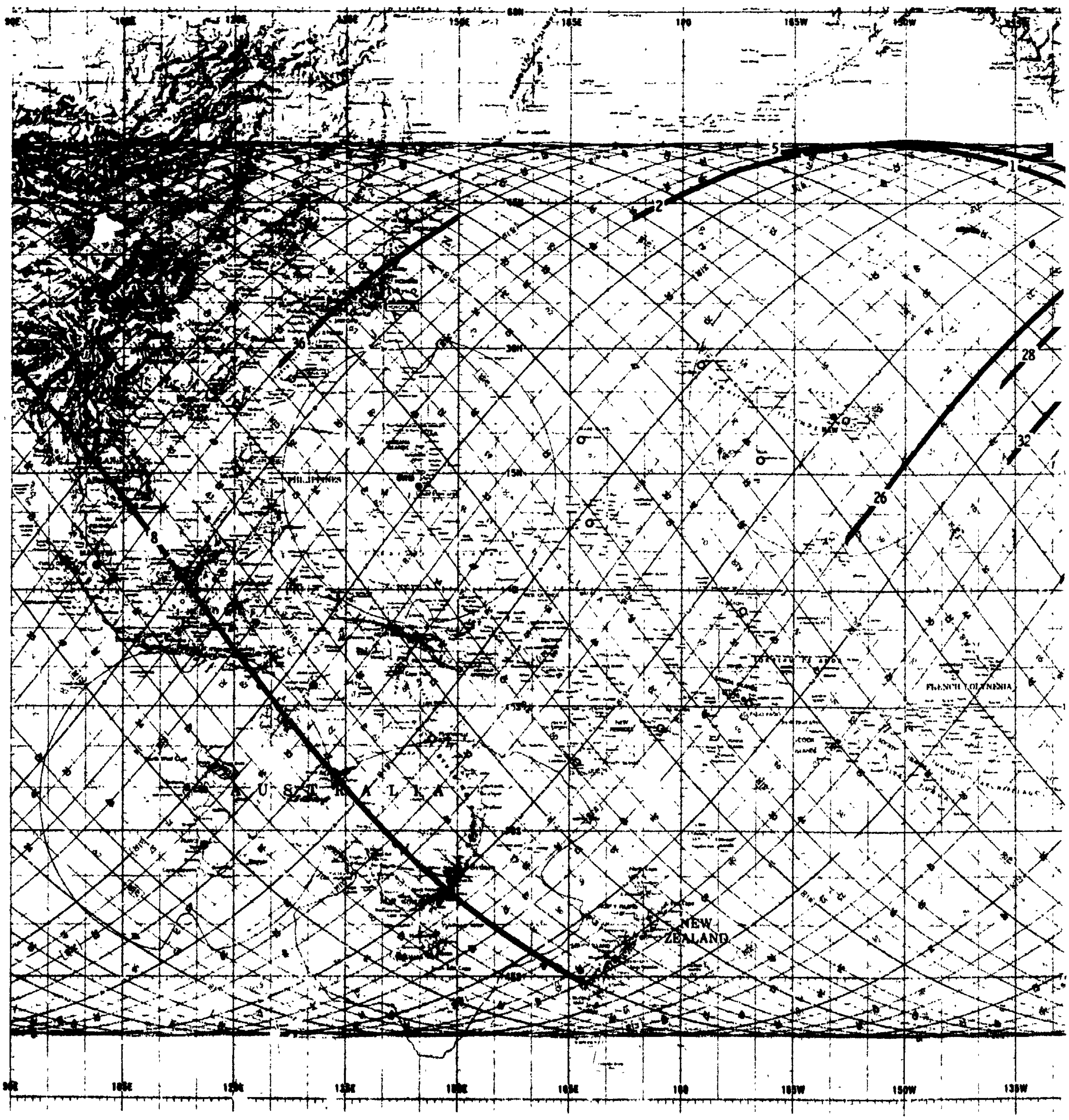
TABLE 12-II.- EARTH RESOURCES EXPERIMENT PACKAGE PASS SUMMARY
(Concluded)

Pass	Track	Revolution	Visit day	Data taking period, min	Longitude, deg	
					Start	Stop
32	16	1791/1792	50	24	136 W	33 W
33	29/30	1804/1805	51	29	114 W	5 E
34	30/31	1805/1806	51	13	128 W	83 W
35	43	1818/1819	52	33	109 W	17 E
36	49	1824	52[a]	—	126 E	150 E
37	58	1832	53	12	112 W	69 W
38	10	1847	54	12	113 W	40 W
39	4	1850	54	15	133 W	60 W
40	19	1865	55	12	131 W	73 W
41	29/30	1875	56	38	98 W	46 E

[a]Earth's limb data also taken on this day.

[b]Lunar calibration data also taken on this day.

FOLDOUT FRAME



FOLDOUT FRAME 2

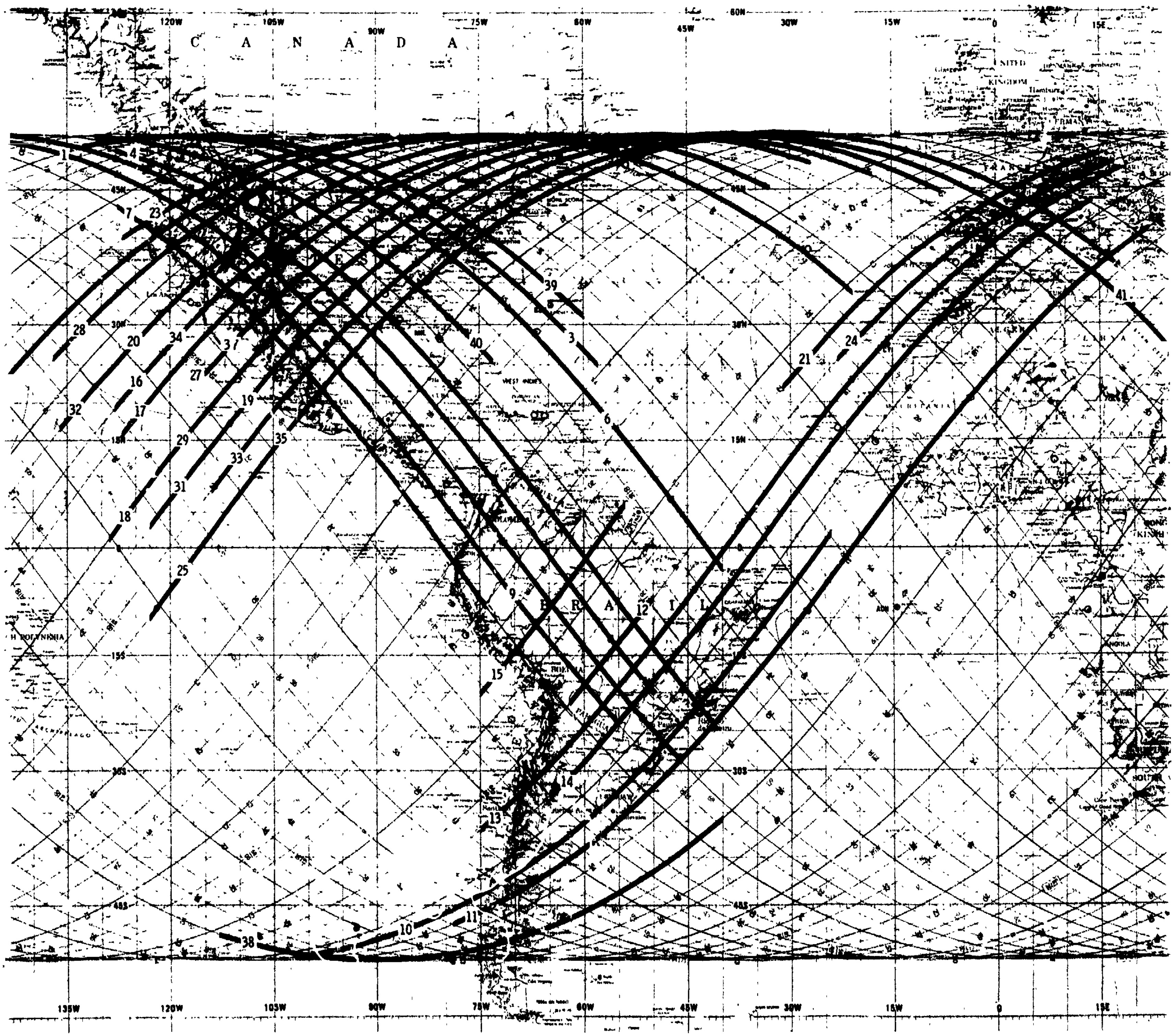


Figure 12-1. - Ear

FOLDOUT FRAME 2

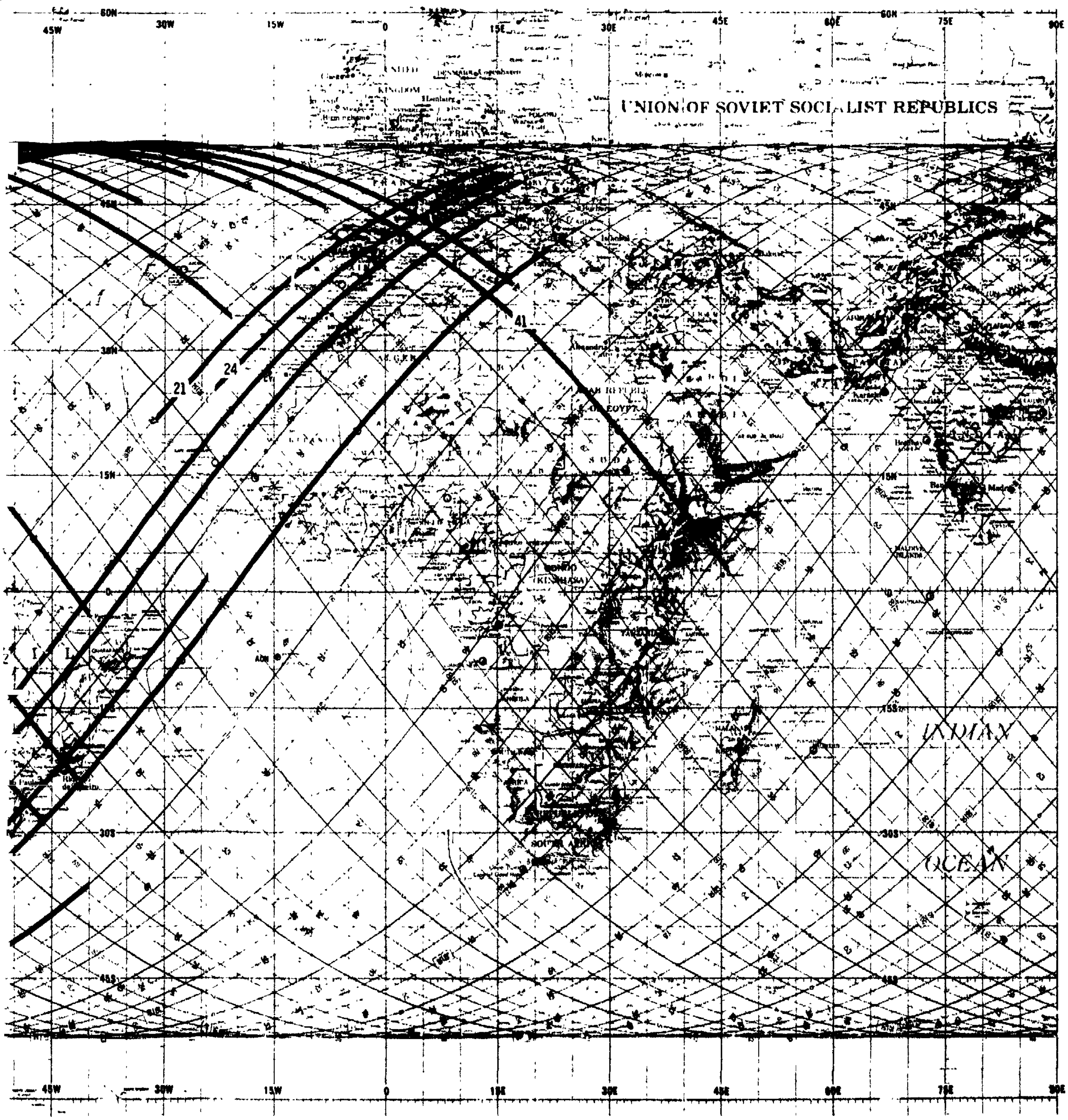


Figure 12-1. - Earth Resources Experiment Package passes during second visit.

The backup deorbit maneuver, if used, would have occurred approximately three revolutions later with the spacecraft landing near the Hawaiian Islands.

Because the orbital ground track had drifted eastward, the premission landing footprint had moved too near land for a primary recovery point. Consequently the footprint was moved northwest. With the more northerly footprint, the targeted landing point was moved within the footprint to the east of the ground track in order to land nearer San Diego, California, and reduce the time required for the recovery ship to reach port.

The sequence of events from undocking to landing are shown in table 12-III.

TABLE 12-III.- SECOND VISIT DEORBIT PROFILE

Event	Preflight profile		Real-time profile	
	G.m.t., hr:min:sec	Differential velocity, meters/sec	G.m.t., hr:min:sec	Differential velocity, meters/sec
Undocking	19:21:33	—	19:49:42	—
Separation maneuver	20:08:19	1.52	—	—
Shaping maneuver	20:55:33	78.79	—	—
Deorbit maneuver	23:57:12	58.49	21:38:18	137
Landing	0:38:29	—	22:19:54	—

13.0 MISSION SUPPORT

13.1 FLIGHT CONTROL

As a result of the increased confidence in the stability of the flight systems, the majority of the flight control effort was concentrated on the scientific activities. Although the systems did not always operate as planned, the majority of the time the ground was able to monitor, analyze, and control most vehicle systems operations, thus freeing the crew to concentrate on experiment operations.

Two major events occurred at the start of the visit that required modifications to flight control operations. The first of these was the motion sickness of the crew and the second was the failures in service module reaction control system quads B and D.

All three crewmen experienced motion sickness to some degree the first three days of the mission. This fact, coupled with a rigid and busy activiation schedule, led to flight plan modifications to allow the crew to recuperate. The crew's progress through the activation checklist was monitored each day and, based on the crew's inputs on their physiological status and experience with activation gained during the first visit, the initial experiment activities and the first extravehicular activity were slipped on a daily basis. Each day's activity was adjusted to a level compatible with the crew's ability to perform. Despite the slower than planned activation sequence, the major medical and Earth Resources Experiment Package operations were started as planned on visit day 5 and visit day 7, respectively. Apollo Telescope Mount operations, being dependent on an extravehicular activity, were the one major visit activity significantly delayed. Since extravehicular activity requires a certain amount of physical exertion and cannot be terminated rapidly once started, plus the fact that the extravehicular activity requires the operation of many Saturn Workshop systems (an undesirable situation until the service module reaction control system problems were better understood), the extravehicular activity was postponed until it could comfortably be done. The delay also allowed major medical experiment runs on both extravehicular activity crewmen prior to the activity, thus giving ground medical personnel a further check of their physical condition. The extravehicular activity was accomplished on visit day 10 and Apollo Telescope Mount operations began the next day (6 days later than planned). The twin-pole thermal shield was also deployed during the first extravehicular activity to insure the continued thermal stability of the Orbital Workshop. The experiment S055 (Ultraviolet Scanning Polychromator Spectroheliometer) door ramp latch was removed because the ramp latch was jamming the door, requiring two-motor operation to open or close the door. As a result, the experiment was returned to a single-motor door operation.

The second major event early in the visit was the second anomaly in the service module reaction control system. The service module reaction control system quad B forward firing engine had developed a leak during rendezvous. The rendezvous was completed easily on three quads, but on visit day 6, service module reaction control system quad D developed a leak and had to be disabled. The loss of opposite quads left the command and service module in a marginal attitude control posture. Rescue mission preparations were begun as a precautionary measure. The second reaction control system failure set in motion the following ground activities: Various functional areas analyzing the failures for a possible generic situation; the rescue vehicle being put into flight readiness; and the rescue flight plan and procedures being detailed as well as the required changes to the existing onboard checklists being produced for use of the command and service module with two quads out.

Two of the five flight control teams were taken out of the team rotation supporting the current visit activities to accomplish the checklist activity. The process of command and service module procedures verification for the two-quad-fail case, performed by the backup crews, led to the conclusion that the command and service module had adequate control with opposite quads out and, by minimizing the required maneuvers, a satisfactory mission termination sequence could be performed. Mission items eliminated were the separation maneuver, and the flyaround inspection. In addition, a single service propulsion system deorbit maneuver was planned. This procedure became the actual entry plan when the quad failures were indeed determined to be unrelated. The rescue vehicle preparations were continued as insurance against future command and service module problems.

The crew went through a "zero g learning curve" just as the first visit crew had done, resulting in a steady increase in the amount of work that was accomplished in a given day. The increased capability manifested itself in crew requests to schedule less time for a given activity, accomplishment of most housekeeping and some troubleshooting without formal scheduling, and heavier scheduling of experiment activities in the presleep and postsleep periods. This latter item generally resulted in one or two extra Apollo Telescope Mount passes every day and added to the science output of the visit.

An average of 42 teleprinter messages were prepared per crew workday, covering activities from standard solar weather forecasts to detailed procedures such as replacing the vehicle rate gyros. As was the case in the first visit, the teleprinter system was a necessity to the conduct of the visit.

Orbital geometry and lighting were such that the major portions of Earth Resources Experiment Package activities occurred early and late in

the visit, leaving the middle of the visit free to accomplish corollary experiments. No Earth Resources Experiment Package passes were run on visit days 17 through 35, thus allowing the flight planning process to implement the corollary requirements.

Experiment operations continued until the planned visit termination with the last Earth Resources Experiment pass (39th) and the last manned Apollo Telescope Mount pass (the 305th manned hour above 400 kilometers) run on visit day 56; the last extravehicular activity (the third) was successfully conducted on visit day 57; and the last medical runs were performed on visit day 58. Experiment and Orbital Workshop deactivation were smooth and accomplished with few procedure modifications.

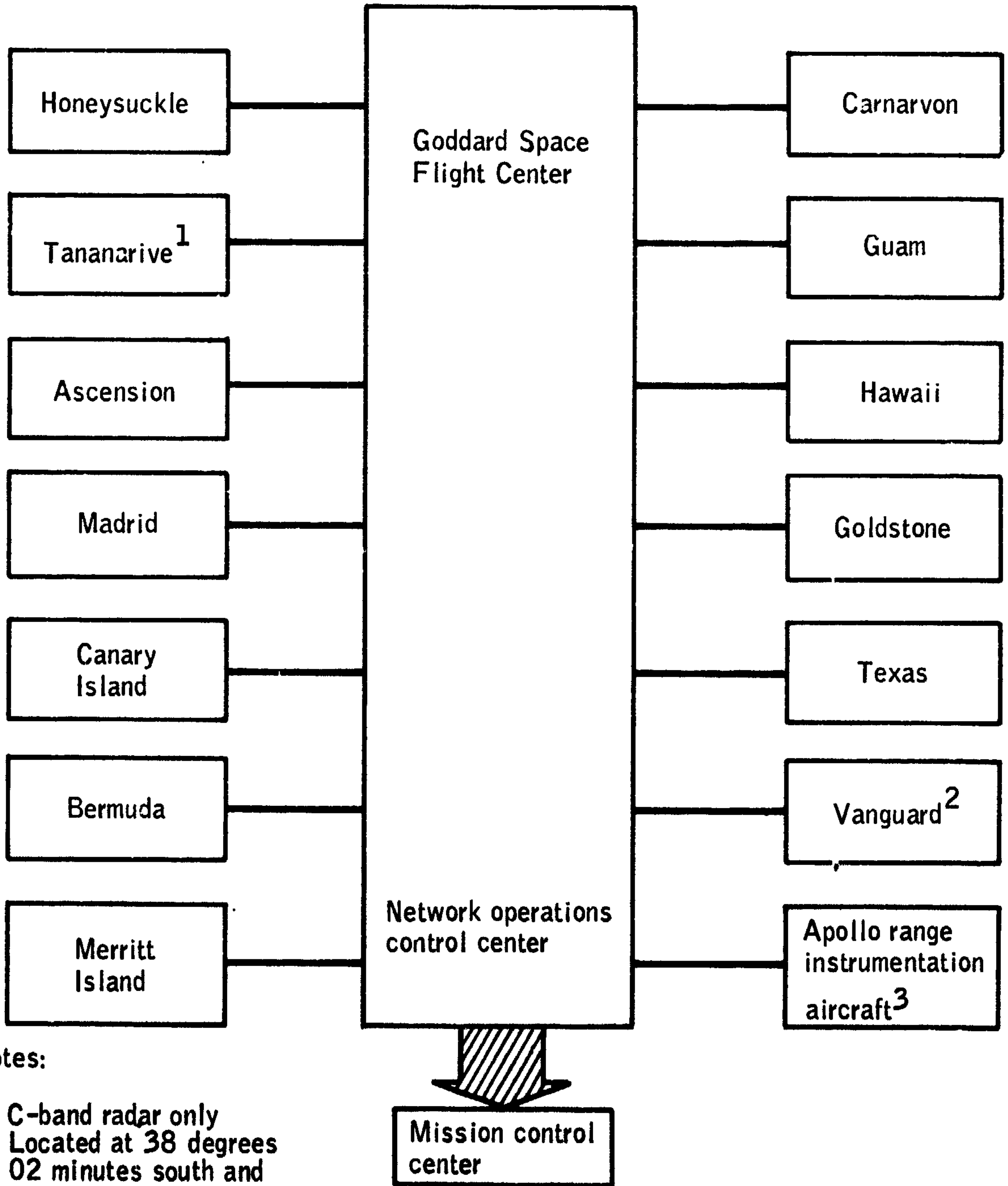
13.2 NETWORK

The Spaceflight Tracking and Data Network for the second visit consisted of the stations shown in figure 13-1. The capabilities were the same as for the first visit except for the deactivation of the station at Newfoundland.

The performance of hardware and supporting software was satisfactory. Data quality was substantially better than the first visit. Several changes that improved the quality were: the range station ship Vanguard was operated at sea to avoid radio frequency interference as experienced on the first visit; flight recorders were dumped only at elevation angles greater than 0.0524 radian to avoid multipath signal problems; several computer program modifications were added to the real time computer complex and remote site data processing computers to improve processing and to correct known discrepancies. A series of data system evaluation tests were conducted to isolate and identify sources of data discrepancies. These tests resulted in computer program changes being added to correct such discrepancies as data spikes and dropouts.

The data overload experienced on the first visit was not experienced on this visit because the overall efficiency of the data system was improved. Also, the transmission of data to Marshall Space Flight Center was more efficient using the computer tape-to-tape system rather than the computer-to-computer memory system.

Although the Spaceflight Tracking and Data Network systems performed as designed, the long periods where no communications were possible between stations clearly demonstrates the need for improved communications coverage. Continuous or near continuous voice and data communications coverage would have significantly simplified the entire operation and enhanced the scientific return.



Notes:

1 C-band radar only
2 Located at 38 degrees 02 minutes south and 57 degrees 32 minutes west
3 With Apollo capabilities

Figure 13-1.- Spaceflight tracking and data network.

On several occasions, configuration and hardware problems were experienced with the VHF private communications. Procedures were revised to more rigorously validate the system prior to station acquisition signal, and to assure a more timely correction of problems when they occurred.

13.3 RECOVERY OPERATIONS

The Department of Defense provided recovery support. The recovery force deployment is outlined in table 13-I.

13.3.1 Prelaunch Through Orbital Insertion

On visit day 1, weather in all launch abort areas was acceptable. After orbital insertion, the recovery forces were released or placed on alert.

13.3.2 Orbital Operations

From orbital insertion through visit day 29, the primary recovery support consisted of inflight refuelable helicopters and an HC-130 aircraft at Hickam AFB, Hawaii, and an duty salvage ship on-call at Pearl Harbor, Hawaii. This support posture was the same as used for the first visit.

On visit day 6, the Recovery Officer was informed of a possible requirement for an early mission termination. Recovery forces were immediately notified and maintained cognizant of mission status.

To support the weekly medical go/no-go decision points commencing with visit day 30, the primary recovery ship, USS New Orleans, sailed from San Diego, California, with a contingent of NASA recovery, biomedical, and public affairs personnel on visit day 22, trained while enroute, and arrived in Pearl Harbor, Hawaii, on visit day 29. The Skylab Mobile Laboratory, and experiment containers/experiment handling equipment/command module depressurization equipment were flown to Hickam AFB, Hawaii, on a C-5 and a C-141 aircraft, respectively, and were loaded aboard the primary recovery ship immediately after its arrival in port. From this time until shortly before the primary recovery ship sailed for end-of-mission support, a contingent of NASA recovery and NASA biomedical personnel was maintained aboard the primary recovery ship.

On visit day 49, after the remaining recovery team personnel had boarded the primary recovery ship, the sailed for the end of visit target point and supported daily target points during the transit across the Pacific.

TABLE 13-I.- SECOND VISIT RECOVERY FORCE SUPPORT

Type ship/ type aircraft	Number	Ship name/aircraft staging base	Area of responsibility
		Ships	
ARS	1[a]	USS Escape	Launch site recovery ship.
ARS	1[b]	USS Grapple	Duty salvage ship providing secondary landing area support until primary recovery ship active.
ATF	1[b]	USS Takelma	
ARS	1[b]	USS Bolster	
LPH	1[a]	USS New Orleans	Primary recovery ship.
		Aircraft	
HH-53C	1[a]	Patrick Air Force Base	Launch site area. Short access time to early launch aborts.
HC-130	2[a] 1[c]	Pease Air Force Base	Support for launch aborts (a) and orbital contingency deorbits (c) in west and mid-Atlantic areas.
HH-3E	1[c]	Loring Air Force Base	Minimum crew retrieval time in west-Atlantic area for launch aborts.
HH-3E	1[c]	Gander International, Newfoundland	Minimum crew retrieval time in west- and mid-Atlantic areas for launch aborts.
HC-130	1[a] 1[c]	Woodbridge RAF, England	Launch abort support (a) and contingency deorbit support (c) in mid- and east-Atlantic areas.
HC-53C	1[c]	Woodbridge RAF, England	Minimum crew retrieval times for east-Atlantic area for launch aborts.
HC-130	1[c]	Hickam Air Force Base	Secondary landing area support until primary recovery ship active. Also for support of the primary backup end-of-mission target point.
HH-53C	2[c]	Hickam Air Force Base	Support from orbital insertion until primary recovery ship active.
HC-130	1[c]	Johnston Atoll Air Force Base	For support of the primary backup end-of-mission target point.
HH-53C	1[c]	Johnston Atoll Air Force Base	
HC-130	1[c]	McClellan Air Force Base	Contingency support in east Pacific area.
HC-130	1[c] 2[a]	McClellan Air Force Base	Support for contingency deorbits (c) and for landing uprange or downrange of end-of-mission landing point (a).
HC-130	1[c]	Eglin Air Force Base	Contingency support in west-Atlantic area.
HC-130	1[c]	Kadena Air Force Base	Contingency support in west-Pacific area.
HC-130	1[c]	Clark Air Force Base	Contingency support in west-Pacific area.
SH-3G	5[a]	USS New Orleans	Primary landing area and end-of-mission support.

[a]Active.

[b]One of three ships active at all times.

[c]On Air Rescue and Recovery Service alert.

In addition to the support in Hawaii, air rescue units at various air rescue bases around the world were prepared to provide support should a contingency landing be required.

13.3.3 End of Mission Support

Recovery support for the primary landing area off the West Coast of the United States was provided by the USS New Orleans. Air support consisted of five SH-3G helicopters from the recovery ship and two HC-130 rescue aircraft from McClellan Air Force Base, California. Three of the helicopters carried underwater demolition team personnel. The first, designated "Recovery," also carried the flight surgeon and was used for command module retrieval operations. The second helicopter, designated "Swim," served as backup to "Pecovery" and aided in the retrieval of the forward heat shield. The third helicopter, designated "ELS" (Earth Landing System), aided in the retrieval of the three main parachutes. The fourth helicopter, designated "Photo," served as a photographic platform for motion-picture photography and live television coverage. The fifth helicopter, designated "Relay," served as a communications relay aircraft. The HC-130 aircraft, designated "McClellan Rescue 1" and "McClellan Rescue 2," were positioned to track the command module after it exited from S-band blackout, as well as to provide pararescue capability and optimize the capability for locating the command module had it landed uprange or downrange of the target point. Figure 13-2 shows the relative positions of the recovery ship, its aircraft, and the HC-130 aircraft prior to landing; as well as the target point, the crew readout of the computer landing point (while on main parachutes), and the estimated landing point.

If the nominal deorbit maneuver had failed to occur, a backup target point for a deorbit maneuver utilizing two service module reaction control system firings was selected southwest of Johnston Island. Landing would have occurred on the third revolution after the nominal end-of-mission revolution. Recovery suport for this backup target point consisted of an HH-53 helicopter and an HC-130 tanker aircraft pre-positioned at Johnston Atoll Air Force Base, Johnston Island, and an HC-130 aircraft located at Hickam Air Force Base, Hawaii. If a service propulsion system failure had occurred, all three aircraft would have been on station at the backup target point at landing. The helicopter, designated "Recovery," carried pararescue personnel and two flight surgeons and would have been used for crew retrieval. The HC-130 aircraft, designated "Johnston Rescue 1" and "Hawaii Rescue 1," were to be positioned to optimize tracking of the command module during entry, as well as to provide optimum capability for locating the command module plus pararescue capability should the command module land uprange or downrange of the target point. Additionally, Johnston Rescue 1 functioned as a tanker aircraft for the recovery helicopter, and both HC-130 aircraft would have been used to maintain electronic and/or visual contact with the command module until command module retrieval was accomplished.

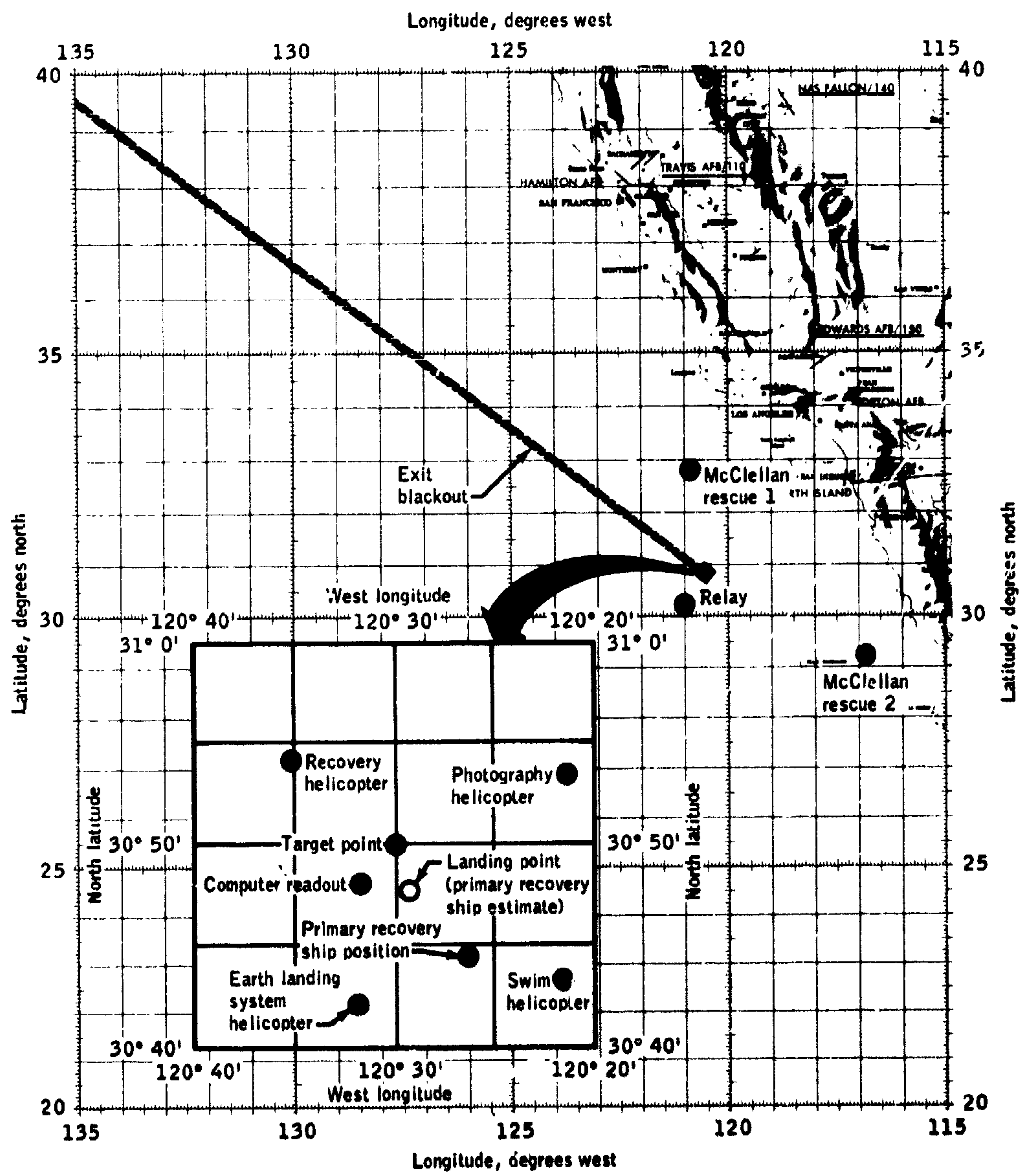


Figure 13-2.- Recovery force deployment for second visit.

13.3.4 Command Module Location and Retrieval

Weather in the end of mission area on recovery day was acceptable. At landing, the cloud coverage was 0.3 at 610 meters; winds were 35 kilometers per hour from 10 degrees true; there were 1/2-meter wind waves on top of 2-meter swells; and the water temperature was 291.5° K. Details of the recovery timeline are shown in table 13-II.

The command module landed at 22:19:54 G.m.t. Based upon navigation satellite (SRN-9) fixes obtained at 20:12, 20:36, and 23:12 G.m.t., and a long range navigation fix at 20:45 G.m.t., the USS New Orleans' position at the time of landing was calculated as 30 degrees 44 minutes 30 seconds north latitude, and 120 degrees 26 minutes 24 seconds west longitude. Using this position of the ship, plus visual bearings and radar ranges, the landing point coordinates of the second visit command module were determined to be 30 degrees 47 minutes 36 seconds north latitude, 120 degrees 29 minutes 24 seconds west longitude. The crew readout of the computer landing point (while on main parachutes) was 30 degrees 48 minutes north latitude, 120 degrees 31 minutes 48 seconds west longitude.

Upon landing, the command module went to the stable II attitude, but uprighted after the uprighting bags had inflated. The Skylab crew was never able to receive voice communications from the recovery forces after command module landing. (See section 7.4 for a discussion of this problem.) The swimmers were deployed to the command module and the flotation collar was installed and inflated. The flight crew remained inside the command module until it was retrieved by the USS New Orleans about 42 minutes after landing. After a medical check in the spacecraft by doctors, the crew egressed from the command module, sat down in chairs on a mobile platform, were moved to a position next to the Skylab Mobile Laboratory, and walked inside the laboratory.

The flight crew remained aboard the USS New Orleans until completion of the medical examinations 2 days after landing. The crew departed the ship at North Island Naval Air Station, San Diego, California, on September 27, 1973, and were flown to Ellington Air Force Base, Texas, the same day.

The command module was off-loaded at North Island Naval Air Station, San Diego, California, on September 26, 1973. The spacecraft was deactivated and delivered to the contractor's facility on October 1, 1973.

TABLE 13-II.- RECOVERY EVENT TIMELINE

Event	Time, G.m.t.	Time relative to landing, day:hr:min
	September 25, 1973 (visit day 59)	
Radar contact by USS New Orleans	22:09	-0:00:11
S-band contact by McClellan Rescue 2	22:15	-0:00:05
Visual contact by USS New Orleans	22:15	-0:00:05
VHF voice contact	22:16	-0:00:04
VHF recovery beacon contact	22:16	-0:00:04
Command module landing (22:19:54)	22:20	0:00:00
Command module in stable I attitude	22:25	0:00:05
Flotation collar inflated	22:34	0:00:14
Flight crew/command module aboard USS New Orleans	23:02	0:00:42
Hatch open	23:08	0:00:48
Flight crew in Skylab mobile laboratory	23:22	0:01:02
	September 26, 1973 (recovery plus 1 day)	
Time critical experiment removal completed/hatch closed	6:45	0:08:25
Reaction control system depressurization started	6:50	0:08:30
Reaction control system depressurization completed	9:00	0:10:40
Hatch reopened	15:00	0:16:40
USS New Orleans arrived North Island	17:03	0:18:43
Command module hatch secured	19:00	0:20:40
Command module offloaded from USS New Orleans	20:00	0:21:40
Command module in hangar at North Island	20:30	0:22:10
Experiments begin offloading from USS New Orleans	20:30	0:22:10
Experiments loaded on C-141	22:00	0:23:40
Experiments departed North Island	23:28	1:01:08
	September 27, 1973 (recovery plus 2 days)	
Experiments arrive Ellington Air Force Base, Texas	2:16	1:03:56
Experiments delivered to Johnson Space Center	3:15	1:04:55
Flight crew departed primary recovery ship in limousine	20:05	1:21:45
Flight crew departed North Island by aircraft	20:22	1:22:02
Skylab mobile laboratory offloading from primary recovery ship	22:00	1:23:40
Flight crew arrived Ellington Air Force Base, Texas	22:59	2:00:39

TABLE 13-II.- RECOVERY EVENT TIMELINE - Concluded

Event	Time, G.m.t.	Time relative to landing, day:hr:min
	September 26, 1973 (recovery plus 3 days)	
Skylab mobile laboratory loaded aboard C-5	0:45	2:02:25
Skylab mobile laboratory departed North Island	2:05	2:03:45
Skylab mobile laboratory arrived Ellington Air Force Base, Texas	4:56	2:06:36
Skylab mobile laboratory in place at Johnson Space Center	16:30	2:18:10
	September 30, 1973 (recovery plus 5 days)	
Command module deactivation completed	1:00	4:02:40
	October 1, 1973 (recovery plus 6 days)	
Command module departed deactivation site	16:30	5:18:10
Command module arrived contractor facility	22:00	5:23:40

14.0 MISSION OBJECTIVES

All primary mission objectives were accomplished. These objectives were:

a. Perform unmanned Saturn Workshop operations.

1. Obtain data for evaluating the perfo[illegible] of the unmanned Saturn Workshop.

2. Obtain solar astronomy data through [illegible] Apollo Telescope Mount observations.

b. Reactivate the Skylab Orbital Assembly in earth orbit.

1. Operate the Orbital Assembly (Saturn Workshop plus command and service module) as a habitable space structure for up to 59 days after the launch of the second visit spacecraft.

2. Obtain data for evaluating crew mobility and work capability during both intravehicular and extravehicular activities.

c. Obtain medical data on the crew for use in extending the duration of manned space flights.

1. Obtain medical data for determining the effects on the crew which result from a space flight of up to 59 days duration.

2. Obtain medical data for determining if a subsequent Skylab mission of greater than 59 days duration is feasible and advisable.

d. Perform inflight experiments.

1. Obtain Apollo Telescope Mount solar astronomy data for continuing and extending solar studies beyond the limits of earth-based observations.

2. Obtain earth resources data for continuing and extending multisensor observation of the earth from low-earth orbit.

3. Perform the assigned scientific, engineering, technology, and Department of Defense experiments.

Tables 14-I through 14-VII list the experiments, student investigations, subsystem/operational detailed test objectives, science demonstrations, and television requirements assigned to the second visit and defines the degree of completion of each objective. Since the data analyses

are not completed, the tables indicate only the number of planned activities that were completed.

A summary of the objectives accomplished shows a very high degree of completion, especially considering the reduction of experiment time early in the mission caused by the motion-sickness problems. After the first few days, the crew quickly caught up, and during the remainder of the mission, exceeded the preplanned workload. For many experiments, the baseline requirements were exceeded, and a number of experiments planned for the third visit were accomplished.

TABLE 14-1.- MEDICAL EXPERIMENTS

Experiment	Number performed		Remarks
	Planned[a]	Actual	
M071 - Mineral Balance	58	60	Urine collection and body mass measurement accomplished 59 and 58 times, respectively
M073 - Bioassay of Body Fluids	5[illegible]	59	
M074 - Specimen Mass Measurement	3	3	
M092 - Lower Body Negative Pressure			
Commander	17	16	Two facial photographs and 1 whole body photograph of each crewman were also obtained
Scientist Pilot	17	18	
Pilot	17	16	
M093 - Vectorcardiogram			
Commander	17	16	
Scientist Pilot	17	17	
Pilot	17	16	
M110 - Blood Study Series	8	8	Hemoglobin test performed 5 times and urine specific gravity performed 4 times on each crewman
M131 - Vestibular Function			
Spatial Location:			
Commander	3	3	
Scientist Pilot	3	3	
Pilot	3	3	
Oculogyral/Motion Sensitivity:			
Scientist Pilot	6	6	
Pilot	6	6	
Commander	0	3	Three extra runs on Commander
M133 - Sleep Monitoring	21	20	
M151 - Time and Motion Study			
Experiments M092/93 or M092/171	10	10	
Experiments T027/S073 or S183	8	8	
Experiment S190B	5	5	
Pressure garment assembly donning and doffing	3	3	
Maintenance activities on experiment M509	3	3	
M171 - Metabolic Activity			
Commander	8	9	
Science Pilot	8	10	
Pilot	8	9	
M172 - Body Mass Measurement	3	3	

[a]Per premission flight plan.

TABLE 14-II.- EARTH RESOURCES EXPERIMENT PACKAGE
DATA COLLECTION FOR SECOND VISIT

Discipline	Task-sites		Task-sites completed	Task-sites partially completed
	Total	Second visit requirement		
Agriculture/range/forestry	34	33	29	4
Geology	59	59	46	13
Continental water resources	28	23	16	6
Ocean investigations	42	37	20	14
Atmospheric investigations	60	47	48	17
Coastal zones shoals, and bays	18	18	13	4
Remote sensing techniques development	99	83	50	100
Regional planning and development	94	92	74	25
Cartography	40	40	26	10
User agency tasks	84	74	20	44
Total	558	506	342	237

TABLE 14-III.- COROLLARY EXPERIMENTS

Experiment	Number performed		Remarks
	Planned	Actual	
M516 - Crew activities	7	5	Failure of S-73/T027 experiment
S019 - Ultraviolet stellar astronomy	12	27	Scheduled and contingency performances completed
S183 - Ultraviolet panorama	12	14	Some of the experiment S019 film used to collect data for experiment S183
T027/S073 - Contamination measurement and Gegenschein/Zodiacal Light	30	6	Telemetry data only obtained. Photographic records and photometer jettisoned on visit day 8. S063 experiment equipment used for one performance
M487 - Habitability/Crew Quarters	18	18	
T003 - Inflight Aerosol Analysis	20	19	
M509 - Astronaut Maneuvering Equipment	4	6	
S063 - Ultraviolet Airglow Horizon photography	8	12	
S071/S072 - Circadian Rhythm	2	0	Experiment package failed after 34 hours
T002[a] - Manual Navigation Sightings	29	31	
T013 - Crew/Vehicle Disturbances	1	1	
T020 - Foot-Controlled Maneuvering Unit	3	3	
S149 - Particle Collection	3	2	Deployment of third detector cancelled
S228 - Trans-uranic cosmic rays	1	1	
S230 - Magnetospheric particle composition	2	2	
D024 - Thermal control coatings - Recover part on third visit extravehicular activity	1	1	
S015 - Zero Gravity Single Human Cells	1	1	
S150 - Galactic X-ray Mapping	4.5 hours	2.0 hours	See section 16.2
T053 - Laser Beam Assessment	0[b]	2	A third attempt was made, but was obscured by cloud cover

[a]To be performed on a non-interference basis at the convenience of the crew.

[b]Approved and scheduled during the mission.

TABLE 14-III.- COROLLARY EXPERIMENTS - Concluded

Experiment	Number performed		Remarks
	Planned	Actual	
M556 - Vapor Growth of IV-VI Compounds	0[c]	1	
M557 - Immiscible Alloy Compositions	0[c]	1	
M558 - Radioactive Tracer Diffusion	0[c]	1	
M559 - Microsegregation in Germanium	0[c]	1	
M560 - Growth of Spherical Crystals	0[c]	1	
M561 - Whiske-Reinforced Composites	0[c]	1	
M562 - Indium Antimonide Crystals	0[c]	1	
M563 - Mixed III-V Crystal Growth	0[c]	1	
M564 - Halide Eutectics	0[c]	1	
M565 - Silver Grids Melted in Space	0[c]	1	
M566 - Aluminum-Copper Eutectic	0[c]	1	

[c]All M550 series experiments were planned for the third visit, but were performed on the second visit.

TABLE 14-IV.- STUDENT INVESTIGATIONS

Investigation	Number performed		Remarks
	Planned	Actual	
ED11[a] - Atmospheric absorption of heat	(b)	1	Completed. (Additional data previously obtained during first visit
ED12 - Volcanic studies	(b)	1	
ED21 - Libration Clouds	(c)	0	No opportunity available
ED22 - Objects within Mercury's orbit	(c)	1	Data only from Apollo Telescope Mount Joint Observing Program 6
ED23[a] - Ultraviolet from Quasars	1	1	
ED25 - X-rays from Jupiter	1	0	
ED26 - Ultraviolet from Pulsars	1	1	
ED32 - Invitro Immunology	1	1	
ED52 - Web Formation	2	1	Data acquisition camera automatic actuator inoperative; therefore, web forming objective was not accomplished
ED63 - Cytoplasmic Streaming	3	1	Experiment failed - plants died
ED74 - Mass Measurement	4	4	
ED78 - Liquid Motion in zero-g	0	0	Approved for second visit operation during the mission. Attempted, but equipment failed

[a]Candidate investigation.

[b]Investigation conducted using Earth Resources Experiment Package sensors.

[c]Investigation conducted using Apollo Telescope Mount experiment (S052) data.

TABLE 14-V.- SUBSYSTEM/OPERATIONAL DETAILED TEST OBJECTIVES

Experiment	Number performed		Remarks
	Planned	Actual	
20.10 Environmental microbiology	4	4	
20.11 Radiation measurement	59	59	Functional objectives 8 and 9 incomplete
20.14 Orbital assembly contamination	10[a]	2	
20.15 Orbital Workshop heat pipe evaluation	0	3	
20.16 Water sample	1	1	
20.17 Iodine monitor	6	7	
20.18 Carbon monoxide monitor	1	1	
20.19 Spacecraft/launch vehicle adapter deployment observation	1	1	
20.20 Parasol material	1	1	
20.22 Food package (return)	0[b]	1	
20.24 Achilles tendon response	0[b]	1	Performed once on each crewman
20.25 Girth and height measurements	0[b]	2	Performed twice on each crewman
20.26 Urine mass measurement using body mass measurement device	0[b]	2	Performed twice on each crewman
20.27 Collection of sweat samples	0[b]	2	Performed twice on each crewman
20.28 Blood limb flow	0[b]	2	Performed twice on 2 crewmen, and once on 1 crewman

[a]Candidate only.

[b]Approved and scheduled during mission.

TABLE 14-VI.- SCIENCE DEMONSTRATIONS

Demonstration	Performance[a]
SD1 - Gravity gradient effects	
SD2 - Magnetic torque	
SD4 - Momentum effects	
SD5 - Energy loss and angular momentum	1
SD6 - Bead chain	
SD7 - Wave transmission reflection	
SD8 - Wilberforce pendulum	1
SD9 - Water drop	2
SD10 - Fish otolith	1
SD11 - Electro static effects	
SD12 - Magnetic effects	
SD13 - Magnetic electro static effects	1
SD14 - Airplane	2

[a]Schedule and performance determined by crew during mission.

TABLE 14-VII.- SECOND VISIT TELEVISION SUMMARY

(Group I[a])

Number	Name	Remarks
TV-1	M074, Specimen mass measurement device and water drink gun	
TV-2	Meal preparation	
TV-3	Eating	
TV-4	M110, Inflight blood sampling	
TV-5	M172, Body mass measurement device	
TV-7	M092, Lower body negative pressure (part 2)	M092 was divided into two telecasts with part 2 to be performed first. Part 1 (TV-6) was later deleted because of a camera failure
TV-8	M093, Vectorcardiogram	Ergometer protocol
TV-9	M171, Metabolic activity	
TV-10	T013, Crew/vehicle disturbances	
TV-11	Earth Resources Experiment Package instrument operations	Incomplete - Earth Resources Experiment Package pass cancelled
TV-11	Earth Resources Experiment Package instrument operations	Completed
TV-12	Earth Resources Experiment Package tape recorder reloading	
TV-13	Apollo Telescope Mount control and display panel operations	
TV-16	Personal hygiene demonstration	
TV-19	M131, Rotating litter chair	Oculogyral illusion mode
TV-20	M131, Rotating litter chair	Motion sensitivity mode
TV-21	M131, Rotating litter chair	Spatial localization mode
TV-23	S183, Ultraviolet stellar panorama	Modified experiment protocol
TV-25	Spacecraft tour of crew quarters	Could not be completed in one segment
TV-26	Spacecraft tour of airlock module/multiple docking adapter/forward part of Orbital Workshop	
TV-27	Live press conference	
TV-28	Science Pilot highlights	Talk about solar physics
TV-29	Earth Resources Experiment Package telescope view	Volcano in Sardinia
TV-29	Earth Resources Experiment Package telescope view	Spain and France
TV-36	M509, Astronaut maneuvering equipment	Shirtsleeves
TV-41	Rendezvous - View of parasol	Black-and-white picture, camera malfunction

[a]All of this tabulation is in terms of number of telecasts. A single telecast varies in scope from a simple one-scene view out of the window to a tour of several sections of the spacecraft or the seven-scene telecast of the Apollo Telescope Mount control and display panel. These telecasts were performed essentially as planned before the mission.

TABLE 14-VII.- SECOND VISIT TELEVISION SUMMARY

(Group I[a] - Concluded)

Number	Name	Remarks
TV-43	First extravehicular activity - Twin pole sunshade	Onboard video recorder malfunction
TV-43	Second extravehicular activity - rate gyro six-pack	
TV-45	ED74, Mass measurement	
TV-46	S063, Ultraviolet airglow horizon photography	
TV-47	S019, Ultraviolet stellar astronomy	
TV-51	SD5, Angular momentum	
TV-53	SD9, Large water drop	Four telecasts used to meet the intent of the TV-53 plan
TV-53	SD10, Minnows	
TV-53	SD10, Fish eggs and watchlings	
TV-53	SD8, Wilberforce pendulum	
TV-54	SD13, Magnetic effects	Two telecasts needed to complete
TV-54	SD13, Magnetic effects	
TV-55	SD14, Paper airplane	
TV-57	T020, Foot-controlled maneuvering unit	
TV-58	ED32, Invitro immunology	
TV-59	ED52, Web formation	
TV-60	ED63, Cytoplasmic streaming	
TV-61	Crew exercise - Mark I exerciser	Three telecasts needed to complete
TV-61	Crew exercise - Mark II exerciser	
TV-61	Crew exercise - Arm pedaling ergometer	
TV-62	Repair of specimen mass measurement device	
TV-63	Television camera test	No value to television media

[a]All of this tabulation is in terms of number of telecasts. A single telecast varies in scope from a simple one-scene view out of the window to a tour of several sections of the spacecraft or the seven-scene telecast of the Apollo Telescope Mount control and display panel. These telecasts were performed essentially as planned before the mission.

TABLE 14-VII.- SECOND VISIT TELEVISION SUMMARY

(Group II[b])

Visit day	Activity
5	Live pictures of noon meal before the crew had fully adapted to zero gravity
6	Live pictures of the crew in the medical experiment area
7	Earth Resources Experiment Package instrument preparations and view of Lake Michigan through experiment S190A window
8	Jettisoning the defective experiment T027/S073 boom out of the scientific airlock
8	Picture of Apollo Telescope Mount control and display panel used for troubleshooting the onboard video tape recorder
9	S190B, Earth terrain camera operations
11	Pictures of Apollo Telescope Mount control and display panel and M092, Lower Body Negative Pressure device as a verification of successful replacement of the onboard video tape recorder
19	Airlock Module data/voice tape recorder disassembly and troubleshooting
20	M110, Blood sampling
21	M509, Astronaut maneuvering equipment (suited)
22	Tropical storm Brenda
22	Crew day off activities; shower, haircut, gymnastics
22	Minnows
22	ED52, Web formation
23	Tropical storm Brenda
30	ED52, Web formation changeout of prime spider Arabella and backup spider Anita
31	M509, Astronaut maneuvering equipment, special tests to demonstrate precision and flexibility of the maneuvering backpack.
32	ED52, Web formation by backup spider (Anita)
33	T020, Foot-controlled maneuvering unit with modified harness
33	Tropical storm Christine

[b]These telecasts were either planned during the mission or were crew option.

TABLE 14-VII.- SECOND VISIT TELEVISION SUMMARY

(Group II[b] - Concluded)

Visit day	Activity
34	ED 52, web formation
34	Demonstration of Achilles' tendon reflex
34	Tropical storm Christine
35	Tropical storm Christine
36	ED78, liquid motion
38	Tropical storm Delia
39	Tropical storm Delia, landfall at Galveston
39	Tropical storm Delia, landfall at Galveston (2nd telecast)
40	ED78, liquid motion (modified)
43	Televised briefing for third visit crew (part 1)
44	Televised briefing for third visit crew (part 2)
45	Televised briefing for third visit crew (part 3)
45	Pictures of drought area in Africa
48	T020, Foot-controlled maneuvering unit (suited run)
51	Eye, ear, nose, and throat examination
51	Throwing darts with modified fins
53	Circus tricks in zero gravity

[b]These telecasts were either planned during the mission or were crew option.

TABLE 14-VII. - SECOND VISIT TELEVISION SUMMARY

(Group III[c])

Number	Name	Disposition
TV-6	M092, Lower body negative pressure (part 1)	Deleted because one television camera failed
TV-14	Entertainment center demonstration	Accomplished during TV-25 tour
TV-15	Sleep/trash/shower/triangle shoes demonstration	Accomplished during TV-25 tour and some crew option television
TV-29	Earth Resources Experiment Package telescope views, 8 passes	Deleted - inadequate resolution for general interest
TV-30 TV-31 TV-32	Fixed out-the-window views, 8 passes	Deleted - lack of good view opportunities
TV-42	Undocking/flyaround	Deleted - no flyaround planned
TV-43	Third extravehicular activity	Deleted - two extravehicular activities accomplished and unknown risk to camera
TV-48	M133, Sleep monitoring	Deleted - telecast cannot be performed until sleep monitor unit can be disconnected and relocated for good pictures. Experiment M133 extended into third visit

[c]These telecasts were premission requirements, but were not performed as planned. Two of these requirements were met by other telecasts. One requirement could not be met and 24 requirements were deleted.

15.0 FLIGHT PLANNING

15.1 SUMMARY

Flight planning for the second manned visit embodied essentially the same basic techniques developed for the first manned visit. These techniques, described in reference 3, continued to be effective in providing the necessary flexibility to update the premission flight plan on a day-to-day basis in response to the particular mission situation.

An assessment of the mission accomplishments from a flight planning point-of-view is presented in section 15.2.

A discussion of certain changes to the flight planning system adopted for the second manned visit appear in section 15.3.

15.2 ASSESSMENT

Visit accomplishments in terms of particular experiments and test objectives are discussed in section 14.0. The actual distribution of crew time compared to the premission allocation is shown in table 15-I. Both of these sources reflect a high degree of accomplishment during the second manned visit. Many experiments obtained 150 percent or more of their objectives. For example, 305 hours of observation above 400 kilometers with the Apollo Telescope Mount instruments were obtained compared to the objective of 205 hours; and 39 passes were made with the Earth Resources Experiments Package instruments compared to the objective of 26 passes. These accomplishments were made possible for two reasons:

a. After the early part of the mission, the Orbital Workshop systems operated well so that little unscheduled maintenance time was required.

b. The crew requested that experiment activity be scheduled during the presleep and postsleep periods as well as a significant portion of their rest and relaxation periods.

Table 15-I reflects this shift of almost 300 man-hours from the operational category to the experiment category. The manner in which the experiment productivity varied as a function of mission time is also of interest. Figure 15-1 shows this effect for the major experiment categories. During the early part of the mission, experiment productivity fell below the plan as a result of several factors; however, after about the first 10 days, there was a steady increase which was maintained through the end of mission.

TABLE 15-I.- COMPARISON OF ACTUAL CREW TIME ALLOCATION WITH THE PREFLIGHT PLAN

Category	Manhours utili ation			
	Actual		Preflight allocation[b]	
	Hr:min	Percent	Hr:min	Percent
Medical experiments	304.47	7.2	291:22	6.9
Apollo Telescope Mount experiments	452:56	10.7	311:01	7.3
Earth Resources Experiment Package	223:31	5.3	165:23	3.9
Corollary experiments	231:15	5.4	153:45	3.6
Subsystem detailed test objective	7:05	0.2	3:49	0.1
Student experiments	10:49	0.3	10:06	0.2
Operational[a]	3017:04	70.9	3314:45	78.0

[a]Included sleeping, eating, housekeeping, et cetera.

[b]Hours adjusted to account for increased mission duration.

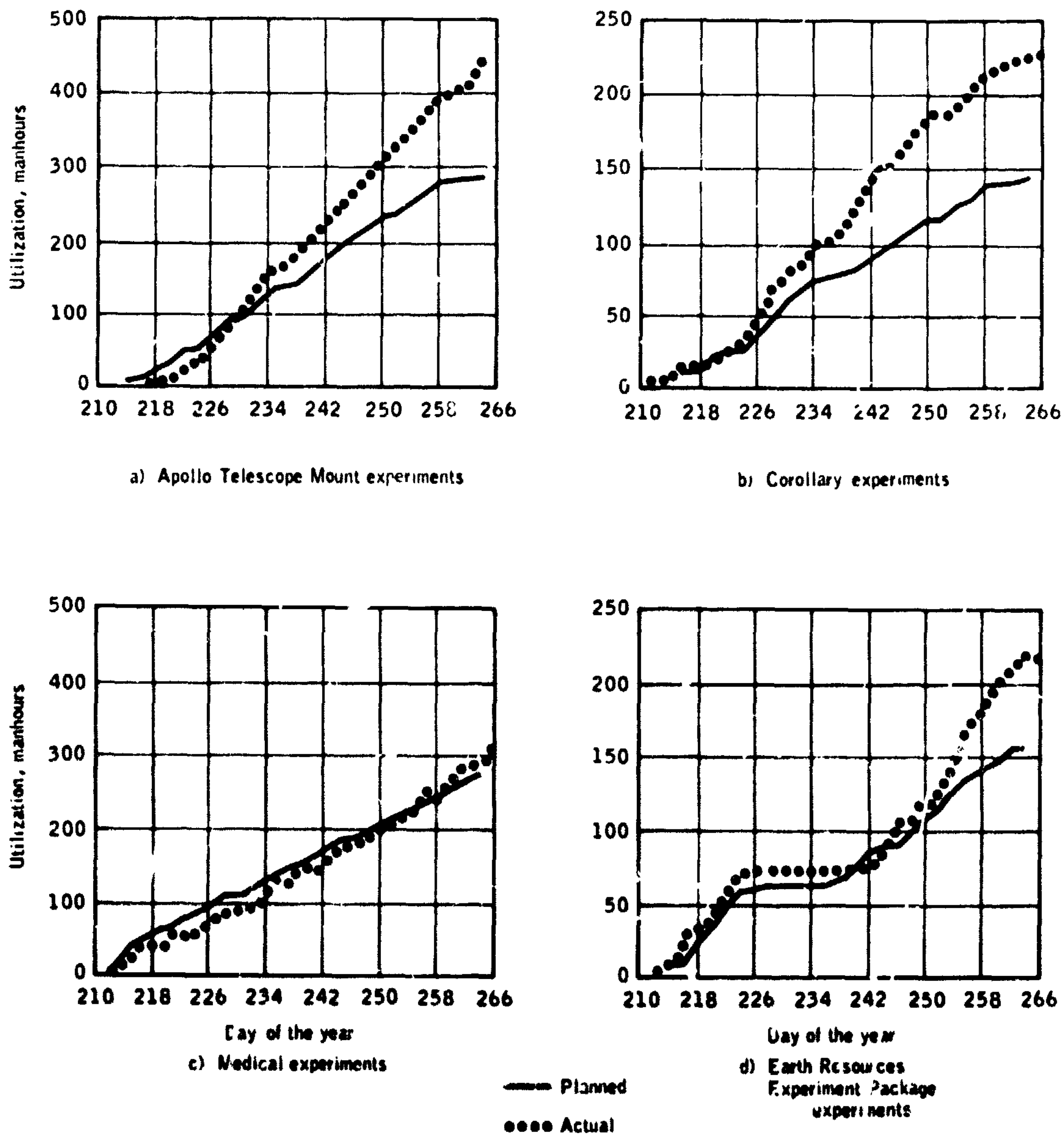


Figure 15-1.- Manhour utilization during second visit.

This increased productivity not only provided the opportunity to gain additional data from the planned experiments, but also made possible the addition of "new" experiments either by utilizing the equipment on board in a different way or by actually performing experiments which were on board but not scheduled until the third visit. This visit was the first time in U.S. manned space flight that such impromptu experiment planning had been attempted. The success is attributed to the skill of the flight crew and to the many other elements of the flight planning system.

15.3 DISCUSSION

As a result of the experience from the second visit, the following items are worth noting:

a. The science planning meetings, held twice a week, were very successful in encouraging participation on the part of the various scientific investigators in the long range planning, especially during some of the busier visit periods. The meetings and their minutes recorded in the Flight Management Team proceedings also provided a useful single source of information concerning science planning. The meetings had been instituted based on recommendations following the first manned visit and will continue during the third manned visit.

b. Several experiments have recurring data gathering opportunities spread throughout the visit. A complete set of these opportunities laid out for the entire visit period in advance together with any special constraints and priorities would have been extremely useful for flight planning. This information was not available in all cases, but a special effort will be made prior to the third visit to insure that these planning data are available.

c. The construction of a preliminary Summary Flight Plan (discussed in reference 3) 2 1/2 days before the use date was valuable in obtaining advance insight into potential planning problems and led to such problems being more easily solved when the Summary Flight Plan was finalized. These preliminary flight plans were made on an optional basis during the second visit; every effort will be made to prepare them on a regular basis during the third visit.

The weekly science conferences with the crew provided an effective means of exchanging information on the progress of experiment, future planning data, and any other experiment-related topics. The conferences

were held on the crew day off, normally lasted for about 1 hour, and involved the direct participation of the Program Scientist as well as representatives from the Apollo Telescope Mount experiment and medical experiment groups. The second visit was the first time that such a direct interchange with the scientists had taken place on a regular basis; the same system is planned for the third visit.

16.0 LAUNCH PHASE SUMMARY

16.1 LAUNCH WEATHER SUMMARY

At launch time, west to southwest air flow prevailed at the surface and up to 4500 meters. Above that level, northwest winds prevailed up to 900 meters. Wind speeds were generally less than 5 meters per second up to 7600 meters. Maximum winds occurred above the 30 kilometer level and were in the range of 35 to 39 meters per second.

A very weak surface low pressure system was located over northeastern Georgia with a weak trough of low pressure extending southward into north-central Florida.

Numerous thundershowers occurred on the previous afternoon with a rather extensive cloud cover remaining over Florida during the night and through the time of launch. Patches of ground fog developed shortly after midnight and, by launch, ground visibility was less than 5 kilometers. Cloud conditions at launch time were broken alto-cumulus at 4500 meters with cirrus above 9000 meters. Radar indicated no echo return within 60 kilometers of the launch pad.

16.2 LAUNCH VEHICLE SUMMARY

The Saturn IB, SA-207, launch vehicle was launched from Launch Complex 39B of Kennedy Space Center. The performance of ground systems supporting the countdown and launch was satisfactory.

The flight trajectory was very close to the planned trajectory. The S-IB stage outboard engine cutoff was 1.13 seconds later than nominal. The total space-fixed velocity at this time was 0.19 meter per second less than nominal. After separation, the S-IB stage continued on a ballistic trajectory until impact. The S-IVB firing terminated with the guidance cutoff signal and was followed by parking orbit insertion, both 3.14 seconds earlier than nominal. An excess velocity of 0.75 meter per second at insertion resulted in an apogee 2.16 kilometers higher than nominal. The parking orbit portion of the trajectory from insertion to spacecraft/launch vehicle separation was near nominal.

All aspects of the S-IVB/instrument unit deorbit were accomplished successfully. The propellant dump was modified during real time to establish a entry trajectory that would enable observation at Kwajalein.

The velocity change obtained for deorbit was very close to the real-time predicted value. The S-IVB vehicle breakup occurred at 81.7 kilometers, and impact was in the primary disposal area.

The S-IB stage propulsion system performed satisfactorily throughout flight. The one propulsion anomaly (possible liquid oxygen emanation from the liquid oxygen tank vents) occurred during countdown and had no effect on the countdown operations or flight performance.

The S-IVB propulsion system performed satisfactorily throughout the operational firing phase and had normal start and cutoff transients. The S-IVB firing time was 448.53 seconds, 4.24 seconds shorter than predicted. An engine pitch actuator oscillation of low amplitude and frequency was noted during prelaunch, S-IB boost, and orbital coast while no commands were being input to the servo-valve. These oscillations were caused by accumulation of millimeter sized particles in the clearance between the servo-valve spool and bushing. Operation was normal during powered flight and the deorbit dumps. The impulse derived from the liquid oxygen and fuel dumps was sufficient to satisfactorily deorbit the S-IVB/instrument unit.

The structural loads experienced during the flight were well below design values. Total vehicle mass was within 0.21 percent of the predicted value from ground ignition through S-IVB/spacecraft separation.

The Skylab experiment S150 (Galactic X-Ray Mapping) was performed during the flight. The object of the experiment was to map the X-ray flux intensity of galactic space. The experiment, which had a planned operating time of 265 minutes, collected X-ray data for only 110 minutes before the experiment high voltage switched off because of low gas pressure in the X-ray sensor.

17.0 ANOMALY SUMMARY

17.1 COMMAND AND SERVICE MODULE ANOMALIES

17.1.1 Service Module Reaction Control System Quad B Positive Yaw (B-3) Engine Oxidizer Valve Leaked

The quad B source pressure and propellant utilization data indicated an abnormal propellant usage approximately three hours after launch. These data, together with the spacecraft rate data and drops in oxidizer manifold pressure, confirmed that the quad B positive yaw (forward firing) engine was leaking oxidizer. TThe crew also reported a "snow storm" on the right side (quad B side) of the spacecraft at the same time. The quad was isolated from the reaction control system at 14:18 G.m.t.

About an hour and a half later, a troubleshooting procedure was conducted that involved electrically isolating the quad B engines, then opening the propellant isolation valves with the helium valves closed (fig. 17-1). Data from this troubleshooting procedure, and from the final three-minute period at 14:18 G.m.t., established that the oxidizer leak rate was about 0.035 kilogram per second through the engine oxidizer valve. The flow rate through a fully open valve is approximately 0.16 kilogram per second. The data prior to 14:15 G.m.t indicated that the leakage started sometime following the first usage of the B-3 engine.

The B-3 engine is the forward-thrusting engine, and when the spacecraft is in prelaunch checkout, the open end of the engine nozzle is up and the outlet of the oxidizer valve is also up, as shown in figure 17-2. The armature in the solenoid-operated oxidizer valve is spring-loaded and contacts metal stops at each end of the 0.51 millimeter stroke. The stellite-faced 1.5708 radian cone of the armature seals against a teflon seat (fig. 17-2) in the closed position. With an armature-to-seat clearance of 0.35 millimeter in the full open position, the valve is sensitive to particulate contamination. To obtain the indicated leakage rate, the armature would need to be held off the teflon seat by about 0.076 millimeter.

Filters are provided in the ground support equipment and spacecraft system lines to the engine, assuring delivery of clean propellant. Records of propellant purity during loading, and the results of subsequent propellant retests indicate no suspect condition. Oxidizer load contamination would be smaller than the 0.005 to 0.015 millimeter rating of the filters in the ground support equipment and in the spacecraft quad B system. Larger particles would be required on the seat to hold the valve open for the leak flow measured. Therefore, particles of sufficient size were either already in the valve prior to loading oxidizer or were introduced through the valve outlet.

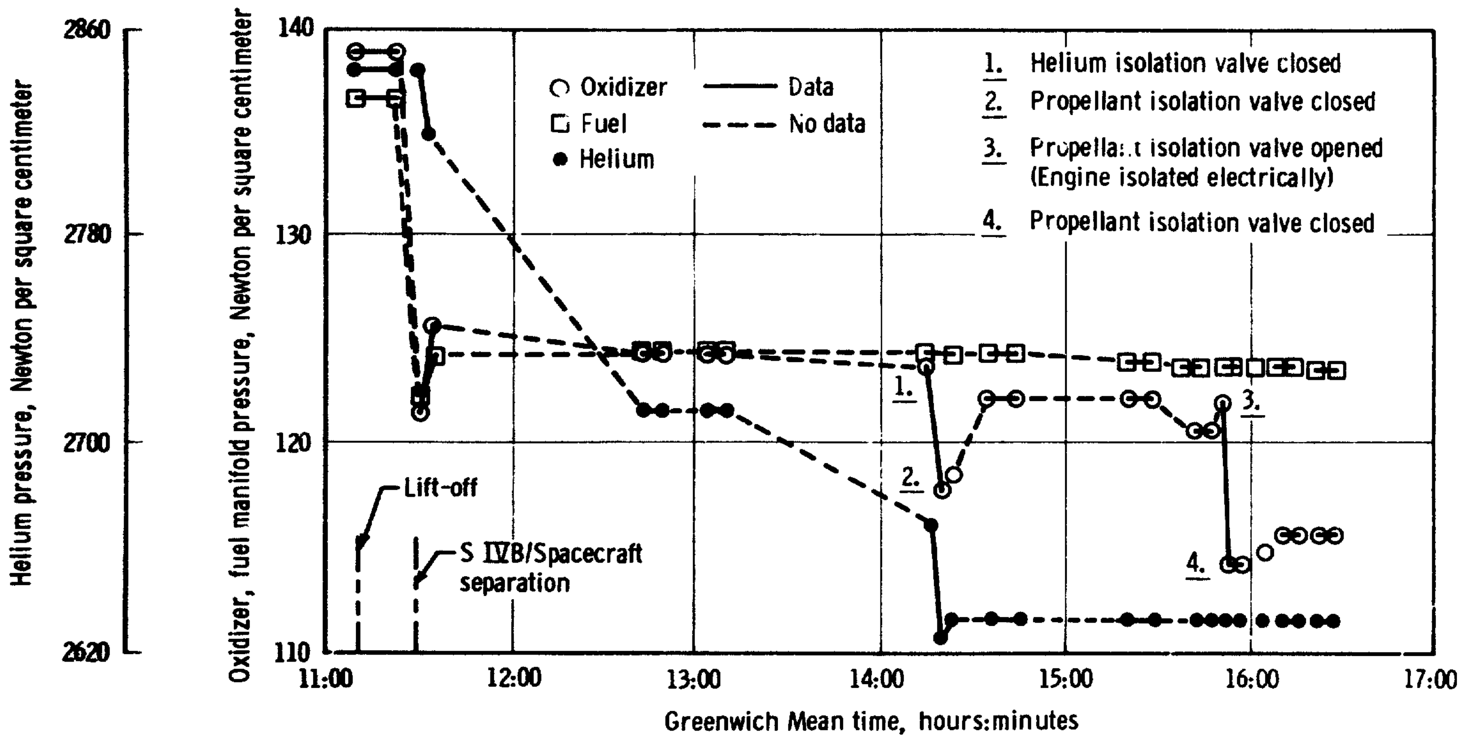


Figure 17-1. - Service module reaction control system quad B propellant data.

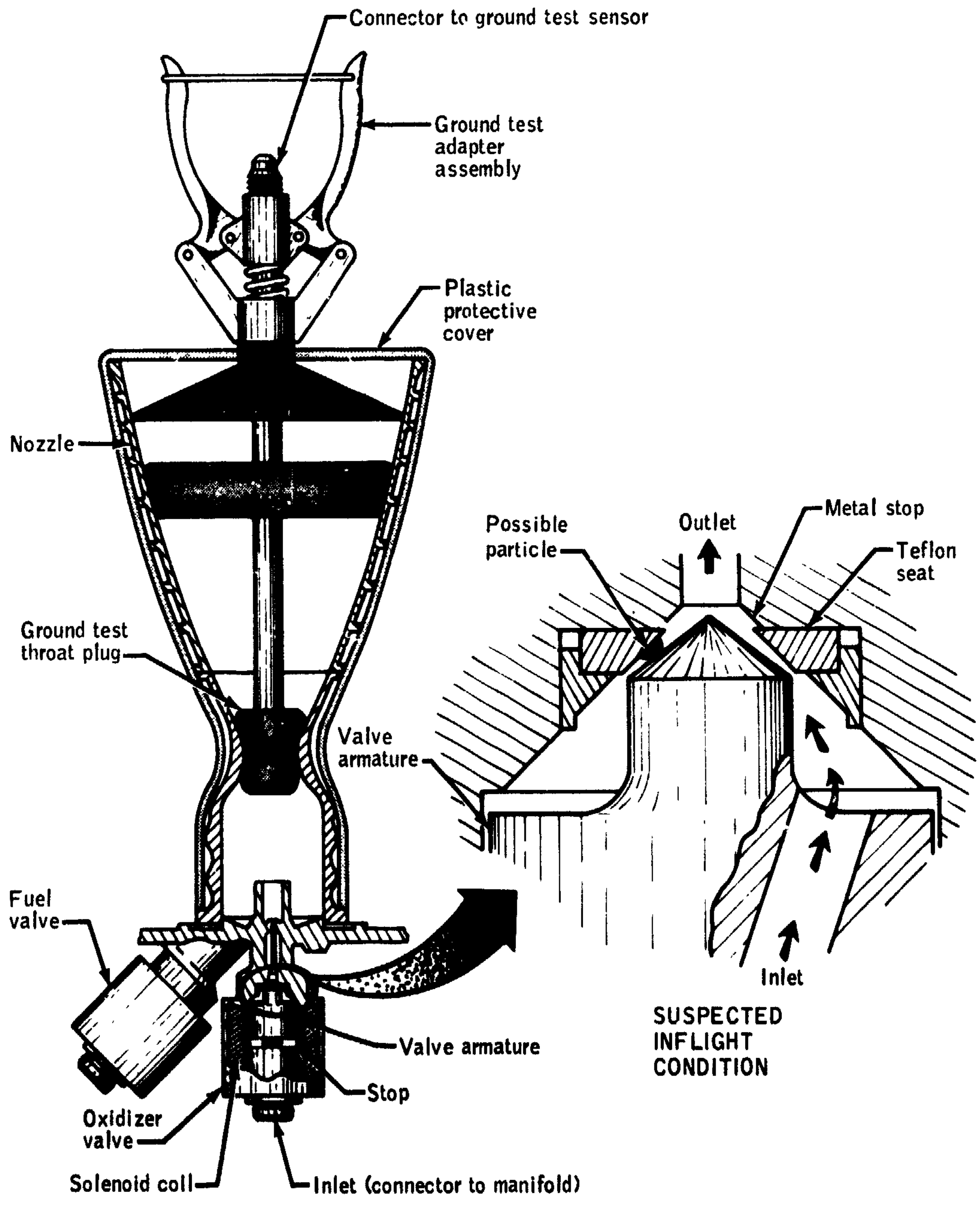


Figure 17-2.- Service module reaction control system quad B positive yaw engine preflight.

Other sources of contamination particles include residue from hot firing tests, or the introduction of particles when the engine covers were removed (with or without throat plugs inserted) for engine injector flow tests, engine valve leak tests, valve signature tests, or stabilization and control system/reaction control system interface tests.

During checkout, plastic covers protect the engine by covering the open end and outside surface of the nozzle (fig. 17-2). To prevent the entry of particles into the nozzle when the throat plug adapter assembly is not installed, the adapter clearance hole in the cover is closed with a piece of tape. When the adapter is installed, but not connected to the ground support equipment lines, the nozzle, cover, and adapter are bagged in place. For transport between buildings (without the adapter), a plastic film is added, over the nozzle opening, and under the protective covers, to keep out contamination.

Design analysis and experience indicate that contamination can enter the valve if the valve is actuated without propellant pressure in the system, but cannot enter when there is pressure on the system. When contamination occurred during some system development ground tests, the particles were sometimes flushed out during oxidizer flow. At other times, the particles were too firmly embedded in the teflon seat to be flushed free.

The need for all checkout personnel to exercise extreme care during vehicle checkout has been reemphasized to prevent entry of contamination when the engine covers are removed, to assure that the valves are not actuated without system pressurization, and to assure the cleanliness of the loaded propellants. In addition, on subsequent missions, all quad engines will be fired in a single burst for a sufficient time to deplete all propellant down stream of the 0.005 to 0.015 millimeter filter. This action will reduce the possibility of trapping a large contamination particle on the teflon valve seat.

This anomaly is closed.

17.1.2 Quad D Oxidizer Leak

Early on visit day 6, the quad D engine package temperature had decreased sufficiently to cause a caution and warning alarm. The service module propellant pressures and system temperatures indicated that oxidizer was venting within the quad D engine housing and propagating through bay five of the service module into the tunnel area, and then exiting through the lower bulkhead near the service propulsion system engine.

Six minutes after the caution and warning alarm, the engine package and quad heaters were enabled and, 83 minutes later, the quad was isolated by closing the propellant isolation valves. Troubleshooting along with data analysis confirmed an oxidizer leak.

The service module reaction control system consists of four individual quad panel assemblies and a propellant storage module. Each assembly (fig. 17-3) has a separate propellant feed system and four engines. The engines are mounted in an engine housing that also encloses an oxidizer and a fuel manifold that feeds propellant to the thruster solenoid valves.

Data analysis indicates that the leak originated in the engine housing area. The probable flow path of the leak, including key temperature changes along that path, is shown in figure 17-4. Equipment in the engine housing from which the leak could have originated includes the four engine assemblies, the Dynatube connectors between the engines and the oxidizer manifold, one machined tee, ten brazed joints, and five lengths of tubing.

The only condition that will match the timeline of events and leakage rates experienced on quad D is an improperly torqued Dynatube connector. Each oxidizer manifold (fig. 17-5), has five Dynatube connectors.

The innermost and primary seal of a Dynatube connector is a mirror-finished metal-to-metal seal. One sealing surface is canted and undercut so that when the nut is torqued tightly, the sealing surface is in compression. This is a Belleville-action seal and provides a spring force along the sealing surface.

The second seal is a concentric groove with a rectangular cross-section on the Dynatube threaded fitting, into which an O-ring is placed and compressed when the nut is torqued.

The problem was first indicated by a quad D package temperature caution and warning signal. Later data showed general cooling in and around quad D caused by the frozen oxidizer. The data showed that the quad D oxidizer leakage probably began about 48 hours after lift-off. In the following three days, only 1.8 kilograms of oxidizer were lost due to seepage. Then, the leak increased sufficiently to vent an additional 11.4 kilograms in 1-3/4 hours. The maximum leak rate experienced was 1.8 grams per second. The quad B package temperature decrease and the oxidizer manifold pressure decrease during the period of the higher rate leak are shown in figure 17-6.

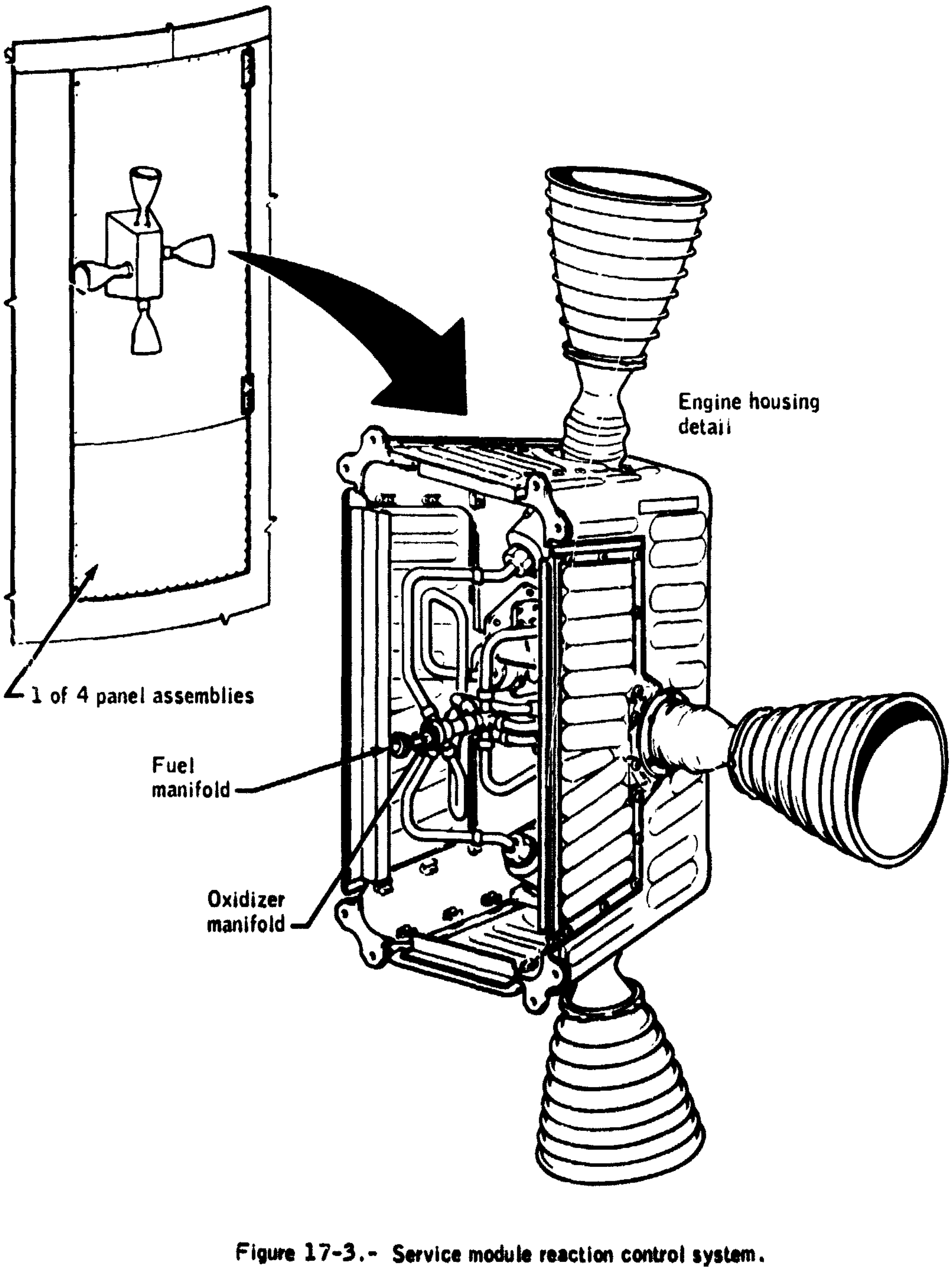


Figure 17-3.- Service module reaction control system.

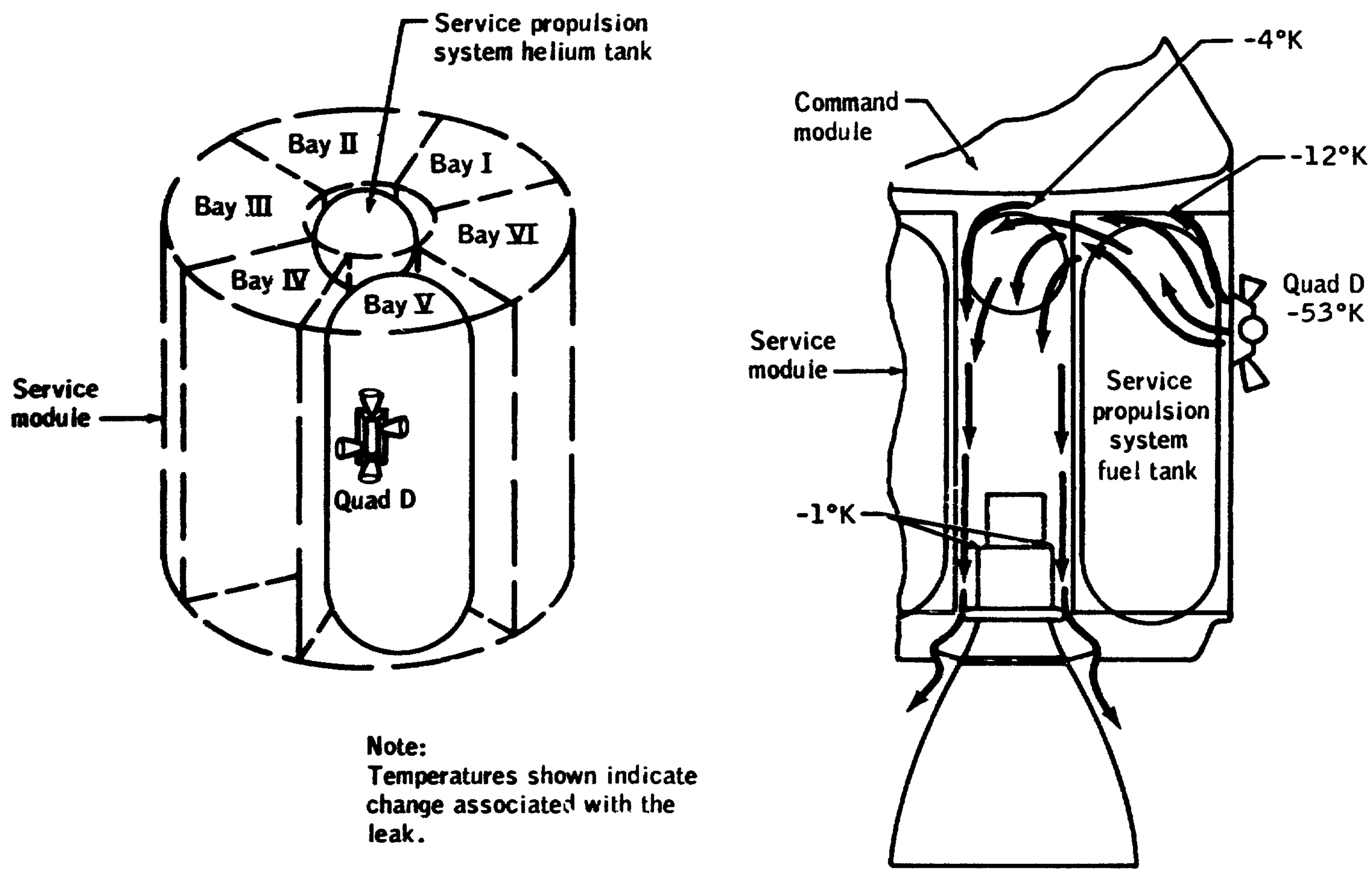


Figure 17-4.- Probable flow path of the majority of the oxidizer.

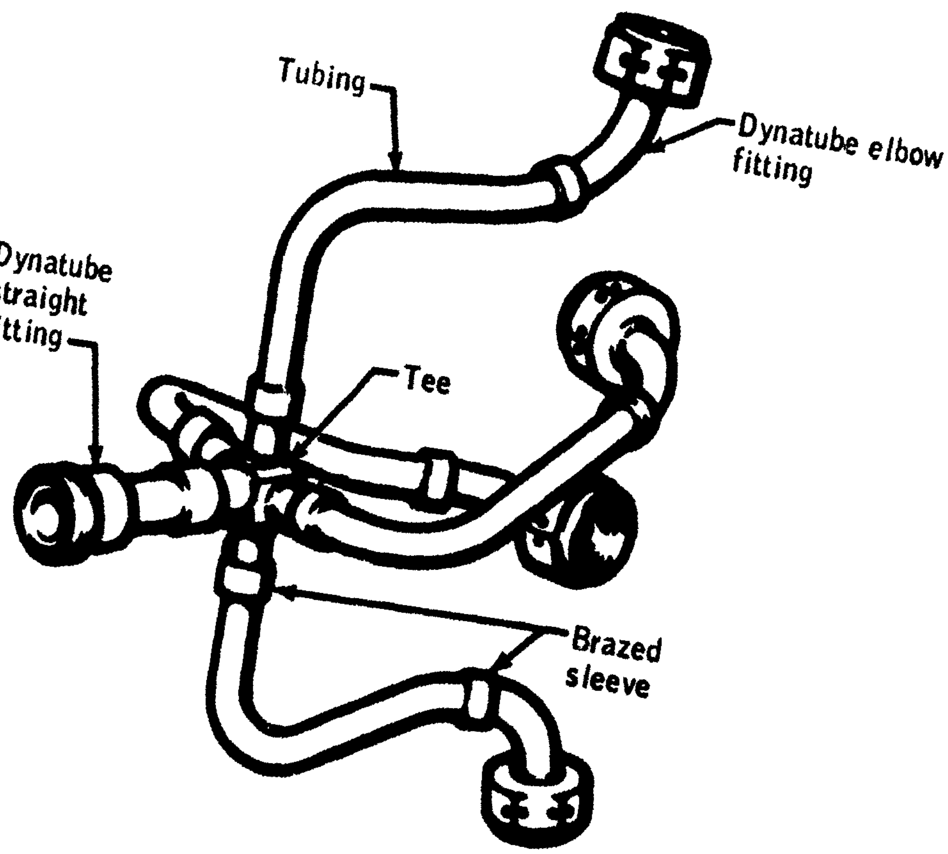


Figure 17-5.- Oxidizer manifold configuration.

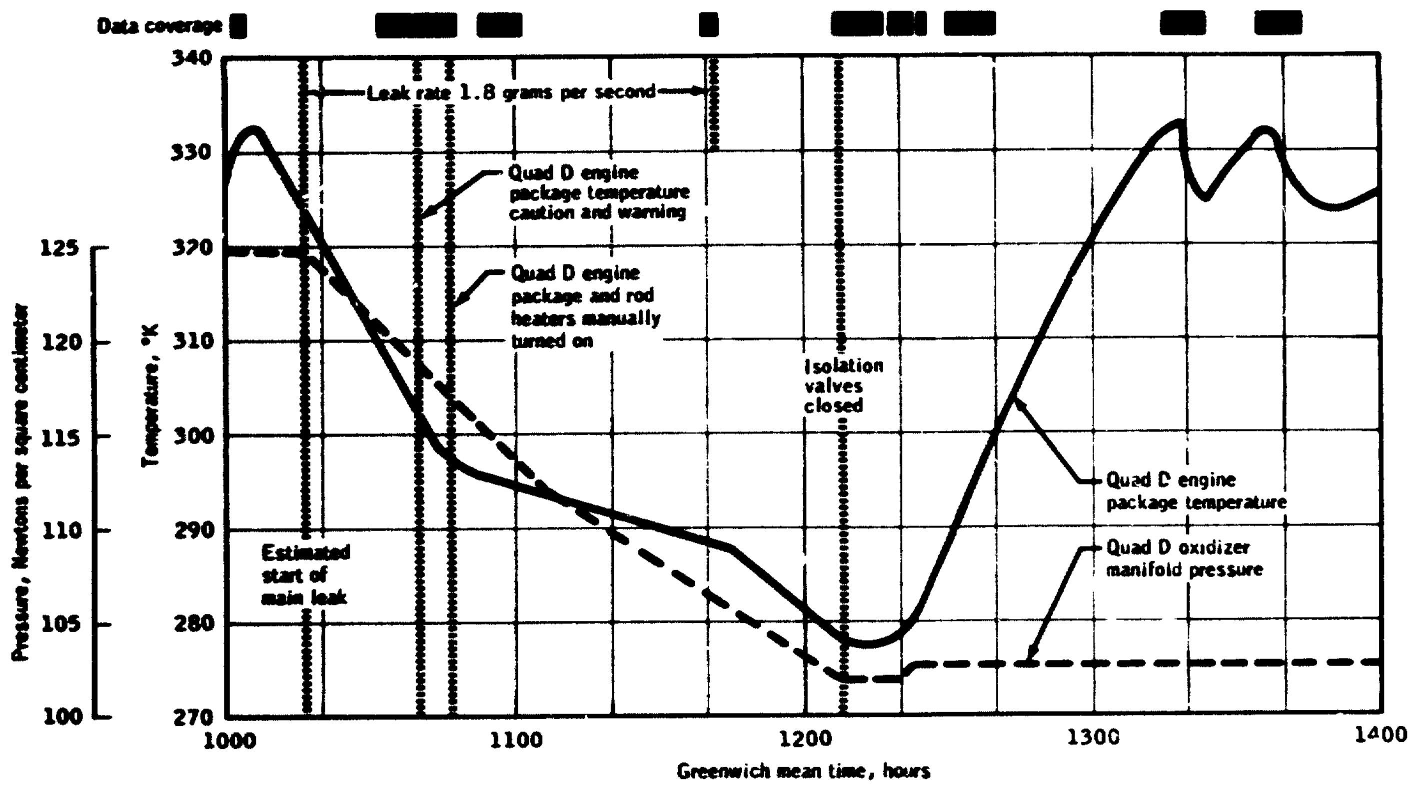


Figure 17-6.- Quad D leakage analysis.

The quad D assembly records indicate that the oxidizer manifold was installed incorrectly in a reversed orientation. When the manifold was reinstalled in the correct orientation, no manufacturing record was made to verify that the manifold was removed and reinstalled or that the connections were properly torqued.

Tests have shown that a finger-tight Dynatube connection (fig. 17-7) will pass the preflight helium leak tests. However, when the reaction control system is pressurized prior to lift-off, the oxidizer penetrates the unmated primary metallic seal and the O-ring alone seals the connection.

Tests have also shown that the butyl O-ring degrades and could start leaking as early as 48 hours after pressurization when exposed to nitrogen-tetroxide at the elevated temperatures and pressures normally experienced in flight. The sharp increase in leakage that occurred five days after lift-off could have resulted from continued degradation and penetration of the O-ring. The O-ring serves no real purpose and, in fact, contributes to degradation of the design in that it prevents the primary seal from being leak checked. This condition is compounded by the fact that the O-ring material selected for this application was not compatible with the fluid that it was to seal.

The present O-rings will be retained on subsequent flights because a properly torqued metal seal will prevent leakage whether or not the O-ring is present. Dynatube connectors on spacecraft 111, 118, and 119 will be retorqued to verify that the primary metal seals are properly mated.

This anomaly is closed.

17.1.3 Cryogenic Hydrogen Tank Wiring Interchanged

On visit day 2, the cryogenic hydrogen tanks were configured with the tank 1 fans and heaters off and tank 2 fans and heaters in automatic for increasing the tank 2 depletion rate. However, pressurization cycles were noted in tank 1 and the tank began to deplete at a faster rate than tank 2. On visit day 11, the tanks were reconfigured with the tank 1 fans and heaters in automatic and the tank 2 fans and heaters off. Pressure cycles and faster depletion rates resulted in tank 2.

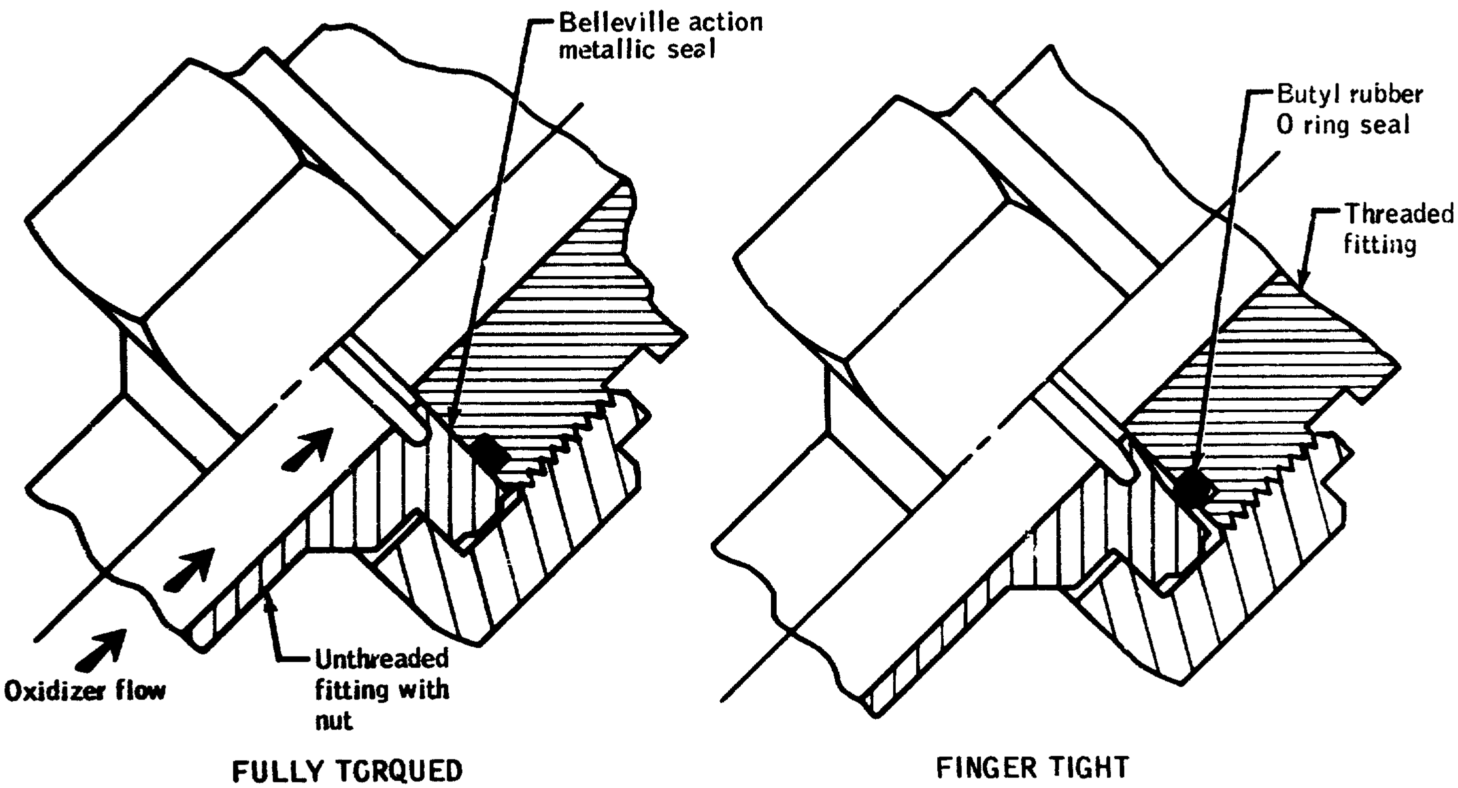


Figure 17-7.- Oxidizer Dynatube connection.

A review of ground test results and crew verification of the switch configuration for visit day 2 and 11 confirmed that the pressure, temperature, and quantity instrumentation was correct and that the data were properly processed.

During installation of the cryogenic shelf on the second visit spacecraft, the cryogenic oxygen instrumentation wiring for tanks 1 and 2 and the hydrogen reactant valve wiring were reversed. These wire reversals were corrected at the spacecraft manufacturing facility during preflight checkout for proper connection. The only wiring in the command and service module that was not verified at the launch site or the spacecraft manufacturer's facility for connection to the proper tank was the vender-supplied wiring from the tank interface to the spacecraft terminal board interface for the fans and the heaters. The wiring for both tanks is color coded identically and both terminal boards are located side by side (fig. 17-8). The hydrogen tank fans and heaters were tested at Kennedy Space Center for proper functioning, but not for proper connection.

The cryogenic hydrogen tank power controls for the fans and heaters were interchanged between tanks 1 and 2 by miswiring at the terminal boards. Tests were implemented on all subsequent spacecraft to verify the fan and heater wiring was connected to the proper tank.

This anomaly is closed.

17.1.4 Improper Updata Link Control of Data Storage Equipment

Each time a data storage equipment stop command was transmitted, the data storage equipment (tape recorder) began rewinding.

The data storage equipment stops when both the forward and rewind commands are absent. Latching relays 1 and 2 (fig. 17-9) are controlled by uplink commands and configured to provide the proper commands to the data storage equipment. When both relays are latched in the set position, the forward command is given. When relay 1 is reset and relay 2 is set, the rewind command is given. The stop command, then, corresponds to relay 2 reset. During the flight, the problem was that relay 2 could not be reset. However, during postflight testing, the system operated properly.

Postflight X-rays of relay 2 (fig. 17-10) showed that a solder ball large enough to jam the relay armature and prevent contact transfer was trapped between the relay cover and frame. The solder ball must have been dislodged from the armature gap by the spacecraft landing shock and became trapped where it was subsequently found.

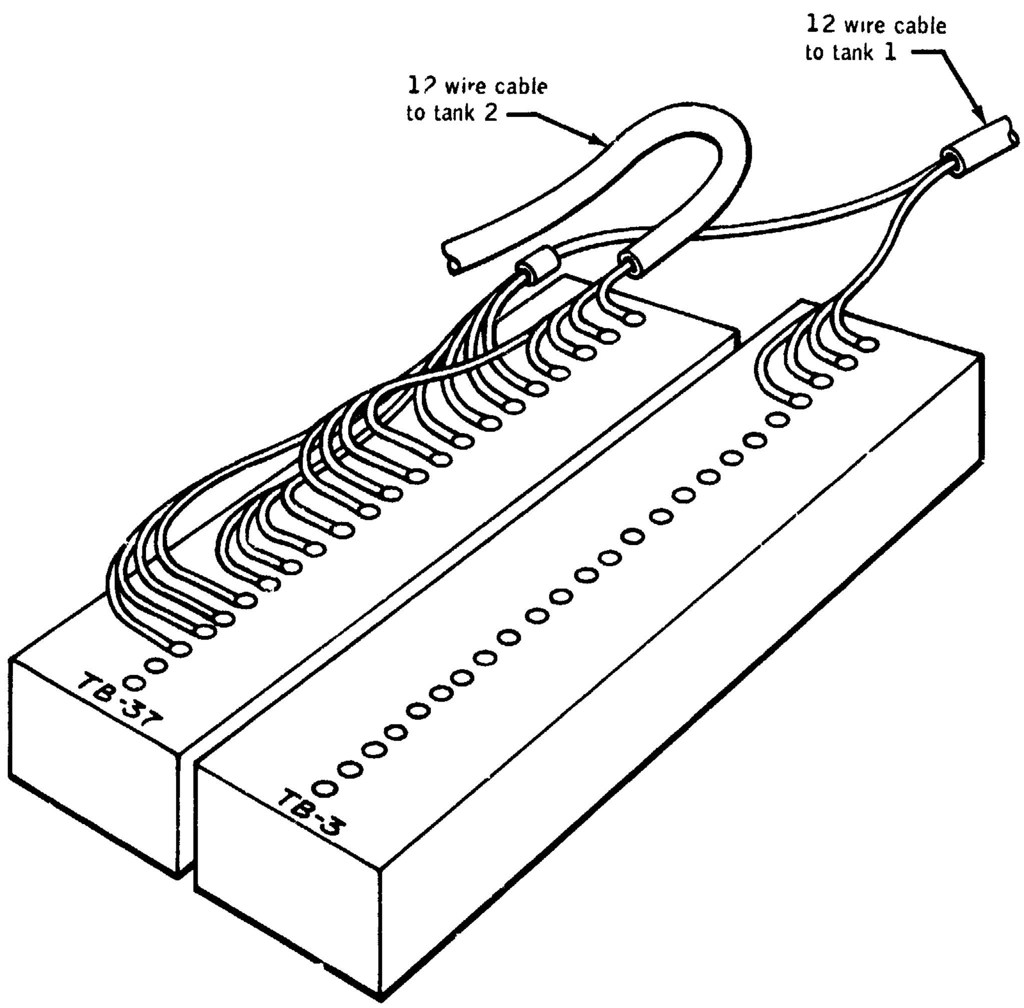


Figure 17-8.- Cryogenic hydrogen tank wiring at terminal boards.

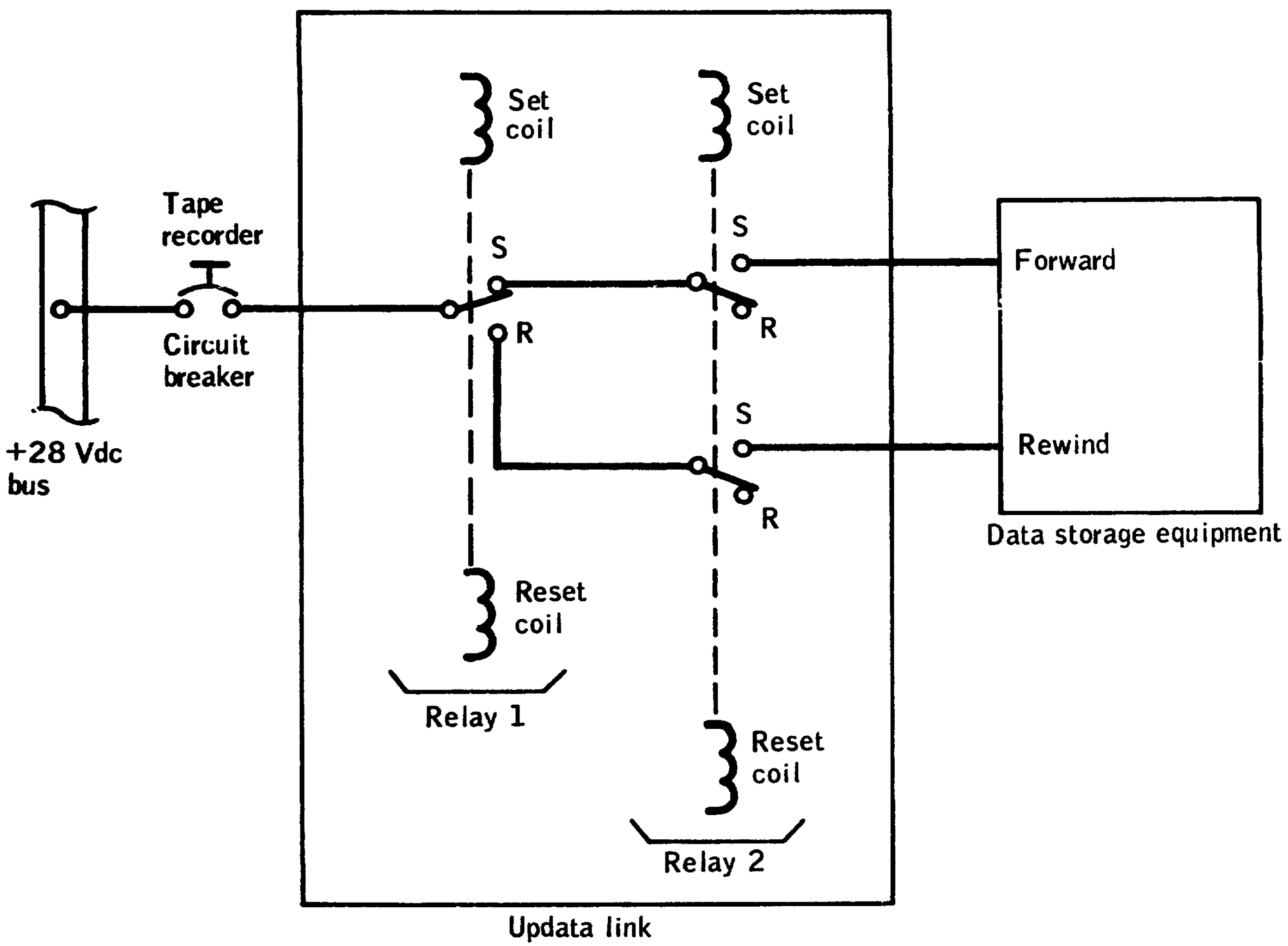
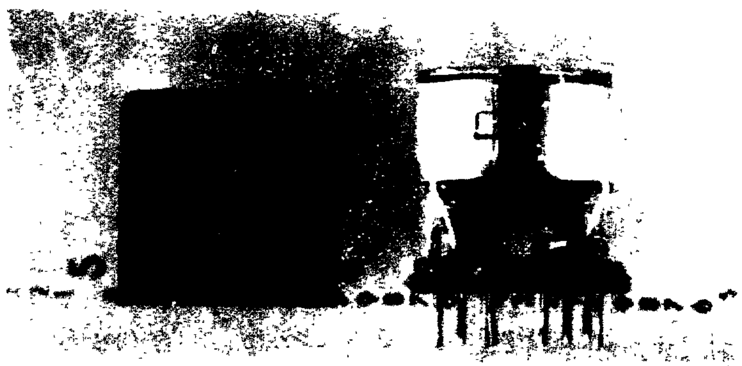
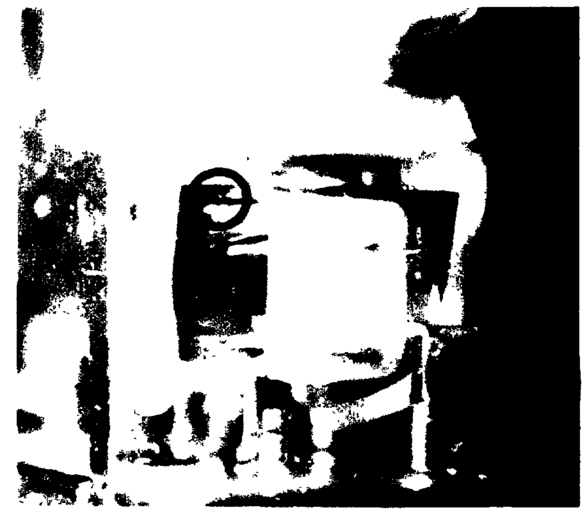


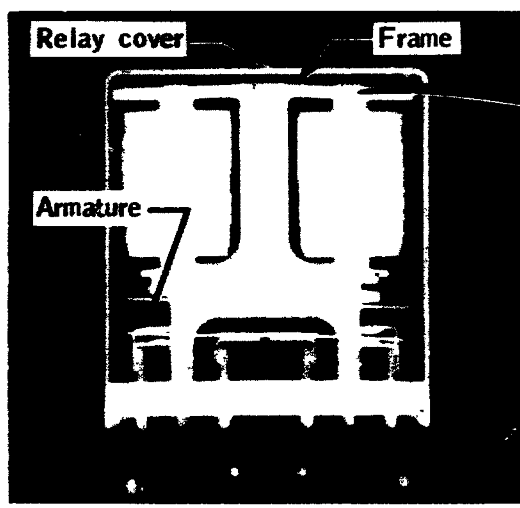
Figure 17-9.- Data storage equipment control.



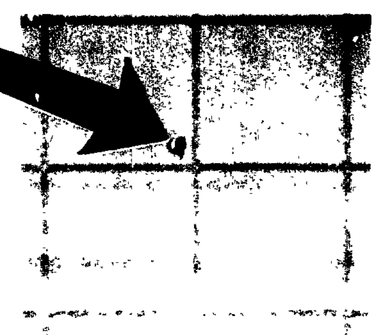
Relay opened



Metallic particle between armature and pole



X-ray taken before relay was opened.



Loose "solder ball" noted in x-ray.

Figure 17-10.- X-rays of relav with loose solder ball.

Manual backup procedures exist for all mission critical functions controlled by the updata link control relays. Consequently, no corrective action is required.

This anomaly is closed.

17.1.5 Service Module Quad B Engine Package Temperature Measurement Failed

On visit day 17, the crew reported a master alarm that was caused by the quad B engine package temperature input to the caution and warning system. The temperature dropped to off-scale low from a normal value of 331° K. A few seconds later, the temperature returned to 331° K. The problem repeated, and the crew inhibited the signal to the caution and warning system. The measurement continued the intermittent operation for 4 hours and finally failed in the off-scale low position.

The engine package temperature sensor is located in the quad B housing (fig. 17-11). The sensor is a platinum resistance thermometer that operates in a resistance bridge as shown in figure 17-12. The transducer is connected to the signal conditioner by a shielded four-wire cable. Two of the four wires are connected to the resistance thermometer, and the remaining two wires are shorted together to compensate for errors introduced by wiring resistance. The bridge output is amplified and fed to the pulse code modulation assembly in the telemetry system.

Prior to September 1969, the manufacturer soldered the compensation wires together. Heat shrinkable sleeving was then installed over the sensor-cable interface to provide strain relief. The heat applied to shrink the sleeving melted the solder which then flowed and wicked between the cable and the sleeving. This solder reflow weakened the connection and resulted in open compensation loop joints.

After September 1969, all new compensation loop joints were brazed. The melting point of the connection was raised from 513° K to 839° K, eliminating the problem. Those connections made prior to September 1969 were screened by heating the sensor housing and cable to 422° K, flexing the cable 0.52 radian at the entry point to the sensor housing, and measuring the compensation loop resistance for changes greater than 0.1 ohm.

The failed transducer was originally manufactured in December 1966, received a new sensor and cable in June 1969, and passed the solder joint screening test. The loss of solder from the joint due to heating of the shrinkable tubing could have occurred in such a manner that the solder joint passed the screening test and opened during flight.

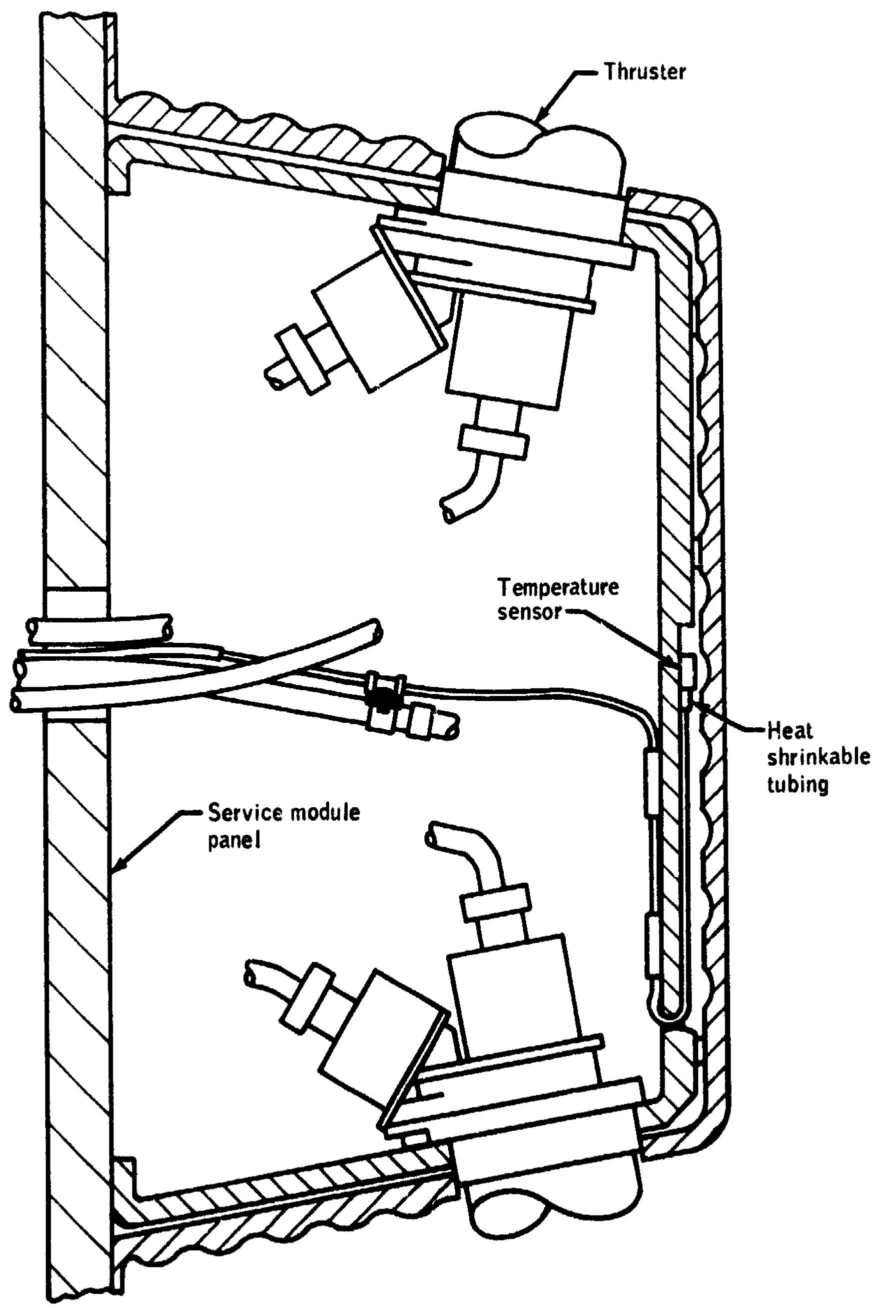


Figure 17-11.- Temperature sensor location in quad housing.

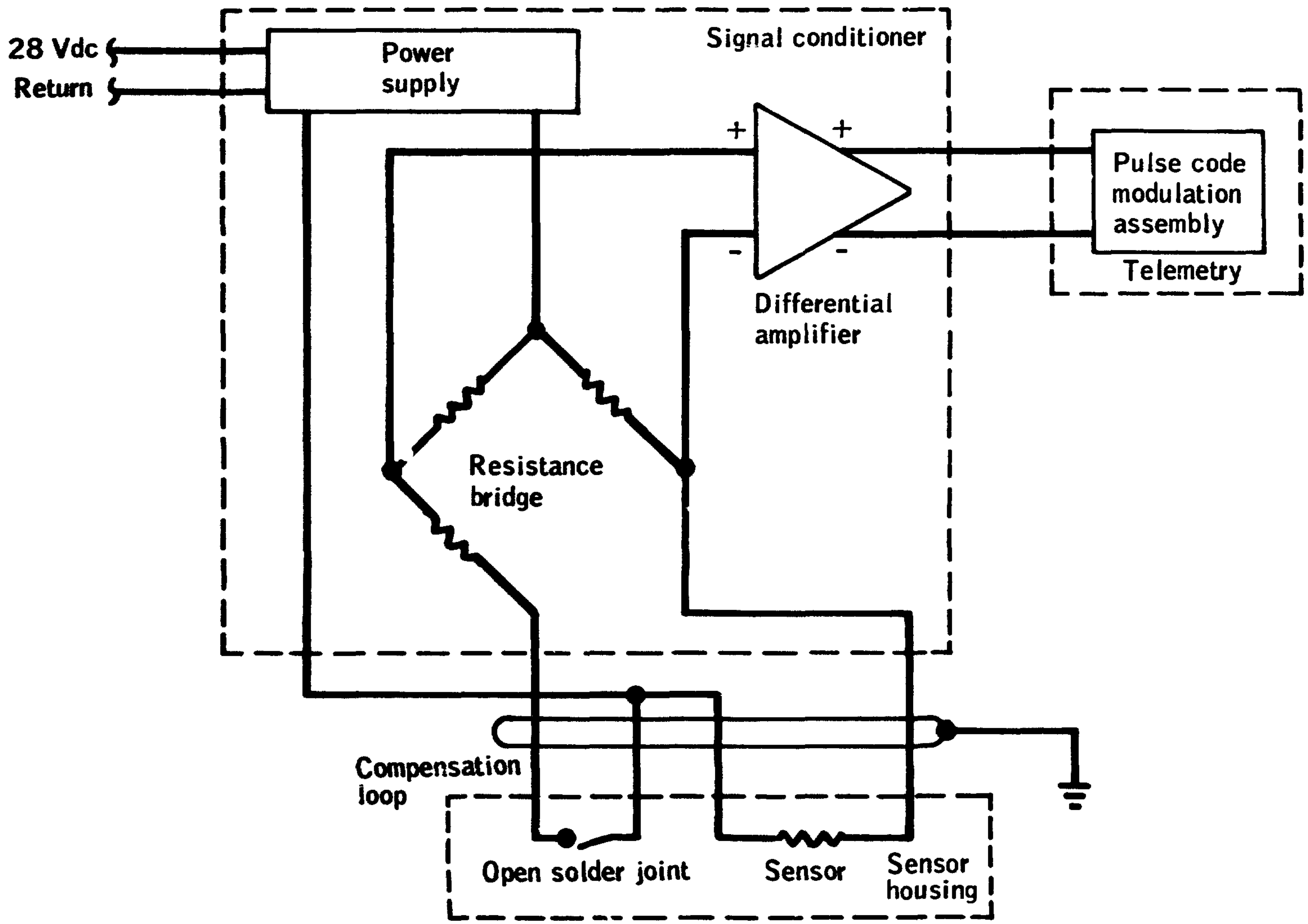


Figure 17-12.- Engine package temperature measurement circuit.

Each reaction control system quad contains a thermostatically controlled heater which may be used to assure that the engines are warm enough to be safely fired. Bus currents were monitored prior to quad B use to insure that the quad B heaters were operational.

This anomaly is closed.

17.1.6 Leak in Primary Water/Glycol Coolant System

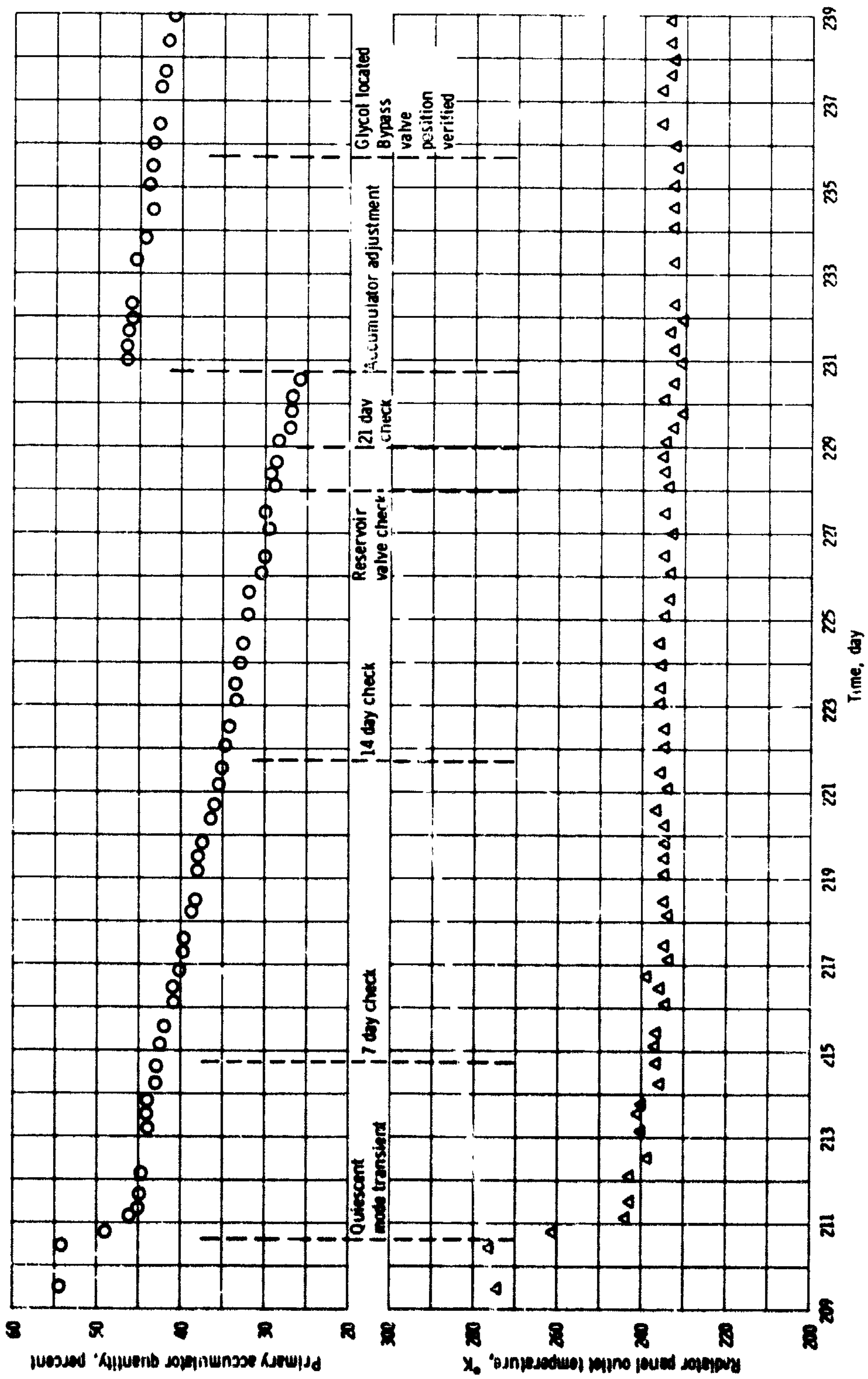
A small quantity of fluid leaked from the command module primary coolant loop into the cabin. The primary coolant loop provides cooling for the command module electrical equipment, the cabin atmosphere, and the crewmen. Heat is absorbed by circulating water/glycol through coolant tubes, coldplates, and heat exchangers, and rejected through the space radiators.

After insertion into earth orbit, the primary water/glycol (coolant) accumulator quantity was adjusted to about 50 percent and the water/glycol reservoir was isolated in accordance with the checklist. After the coolant loop temperatures stabilized, the coolant accumulator quantity decreased at a rate of approximately one percent per day (fig. 17-13). On visit day 19, the crew verified that the reservoir inlet and outlet valves and the accumulator fill valve were fully closed. On visit day 22, the crew confirmed that coolant fluid was not leaking back into the reservoir by cycling the inlet valve and noting that ullage existed in the reservoir. The primary accumulator quantity was increased to about 50 percent (46 percent at the coldest orbit point) on this same day by transferring coolant from the reservoir into the accumulator. The accumulator quantity continued to decrease, but at the reduced rate of about one-half percent per day.

On visit day 27, an estimated 160 cubic centimeters of fluid was found behind an access panel in the area of the suit heat exchanger coolant bypass valve (fig. 17-14). Calculations based on the accumulator quantity measurement indicated that about 320 cubic centimeters were lost during the visit. The valve was manually verified to be in the bypass position and was not repositioned for the remainder of the visit.

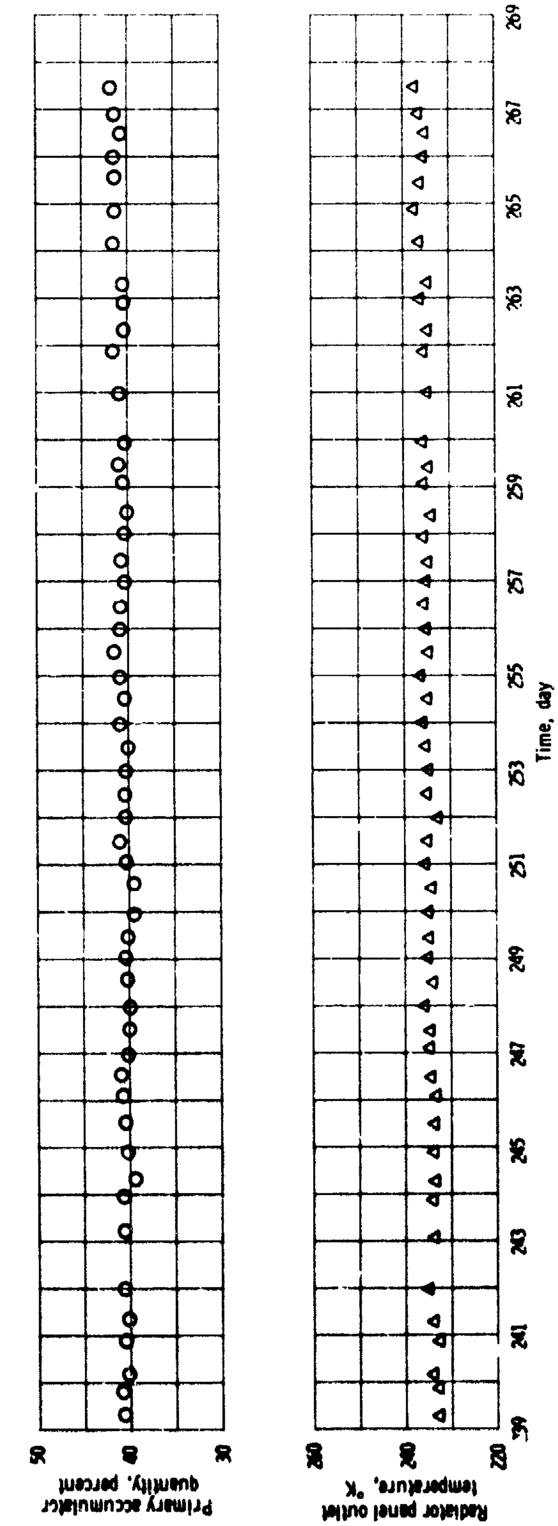
The water/glycol accumulator quantity continued to decrease at the reduced rate until visit day 31, when the quantity stabilized and remained at about 40 percent until the end of the visit.

A postflight leak check was made on the primary coolant system. No leakage was noted with the suit heat exchanger coolant bypass valve in either the flow or bypass position, but leakage was observed when the valve was in an intermediate position. No evidence of leakage was noted in any other area of the vehicle.



(a) Day 209 to 239

Figure 17-13. - Coolant quantity and temperature history.
(Representative cyclic minimums)



(b) Day 239 to 269

Figure 17-13. - Concluded.

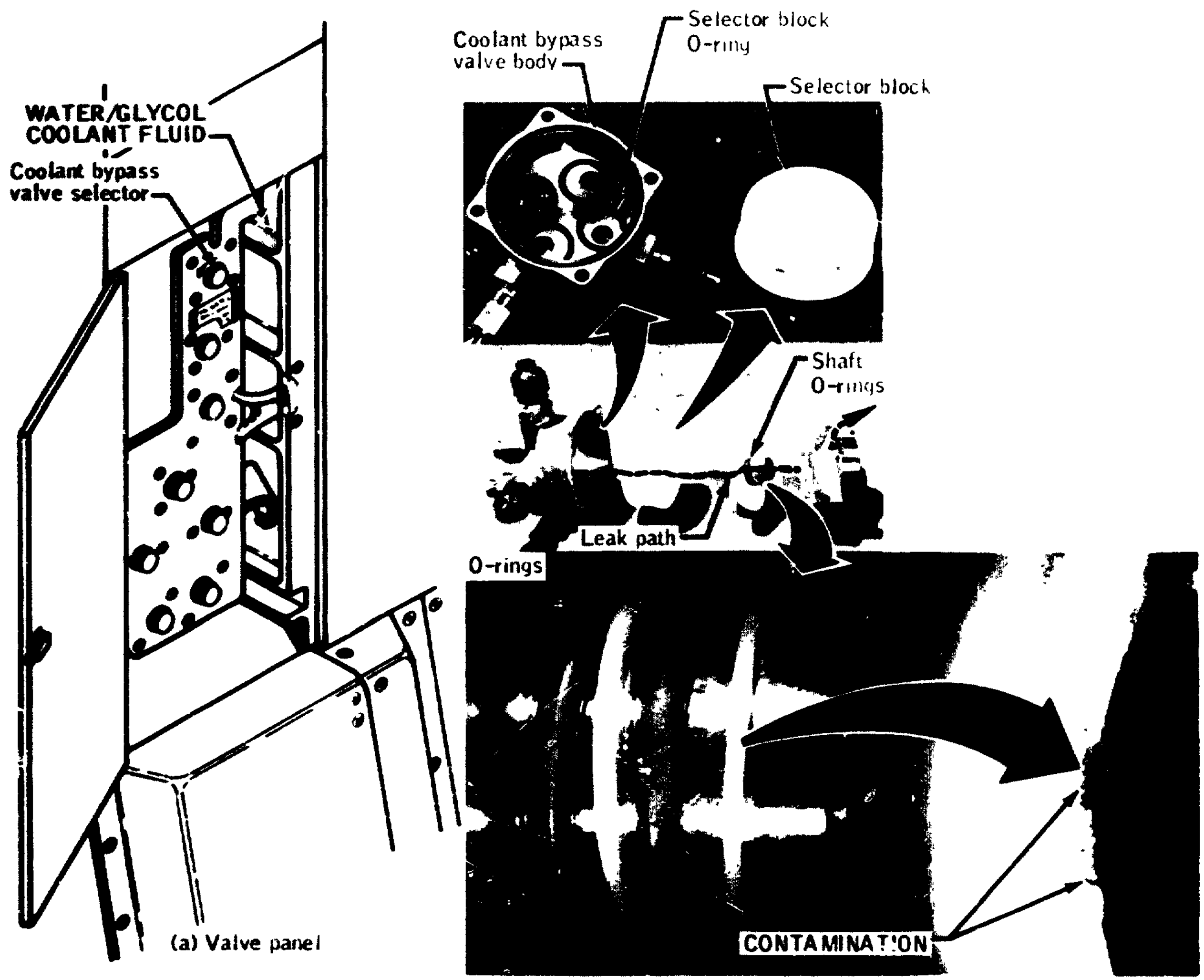


Figure 17-14.- Suit heat exchanger coolant bypass valve.

The leaking valve was removed from the command module and disassembled. The selector block O-rings (fig. 17-14), which form the primary seals in the selector block and valve housing assembly, were in good condition. A small amount of contamination was evident on and around the redundant O-rings on the shaft (fig. 17-14). Analysis indicated that the contamination was gray paint, similar to that used on the command module panels. Contamination on the shaft seals could cause leakage when the valve is in an intermediate position because, in an intermediate position, the primary seal O-rings which encircle the ports in the valve block may not encircle the selector block ports, and the redundant shaft O-rings must perform the sealing function for the valve. However, since the crew verified that the valve was not in an intermediate position, and since the valve was not actuated for four days prior to the leak stoppage, the cause of the leakage is unknown.

Preflight primary coolant system leak tests will be performed on subsequent command modules with the suit heat exchanger coolant bypass valve in the bypass position. In addition, manual positioning of the valve will be used during the mission to ensure positive positioning.

This anomaly is closed.

17.1.7 Apparent Drop in the Service Propulsion System Oxidizer Pressure

On visit day 59, the service propulsion engine interface oxidizer pressure measurement indicated a decrease of 15 newtons per square centimeter from 110 newtons per square centimeter in less than 0.10 second. All other significant system parameters remained constant. Under no-flow conditions, the oxidizer tank pressure measurement should read the same value as the interface pressure measurement, but remained steady at about 111 newtons per square centimeter. Therefore, the change must have been caused by a failure in the interface pressure transducer or signal conditioner.

On visit day 60, during service propulsion system repressurization, the oxidizer tank pressure increased 10 newtons per square centimeter while the interface pressure increased 16 newtons per square centimeter. This confirmed that the characteristics of the oxidizer interface pressure instrument had changed sufficiently to render the output incorrect.

The pressure transducer sensing element is a steel alloy diaphragm that is flexed by the differential pressure between the oxidizer and the 10 newtons per square centimeter reference cavity pressure as shown in figure 17-15. Four small silicon semiconductor strain gages are cemented directly to the inside surface of the diaphragm. They are connected as the four active elements in a resistance measurement bridge.

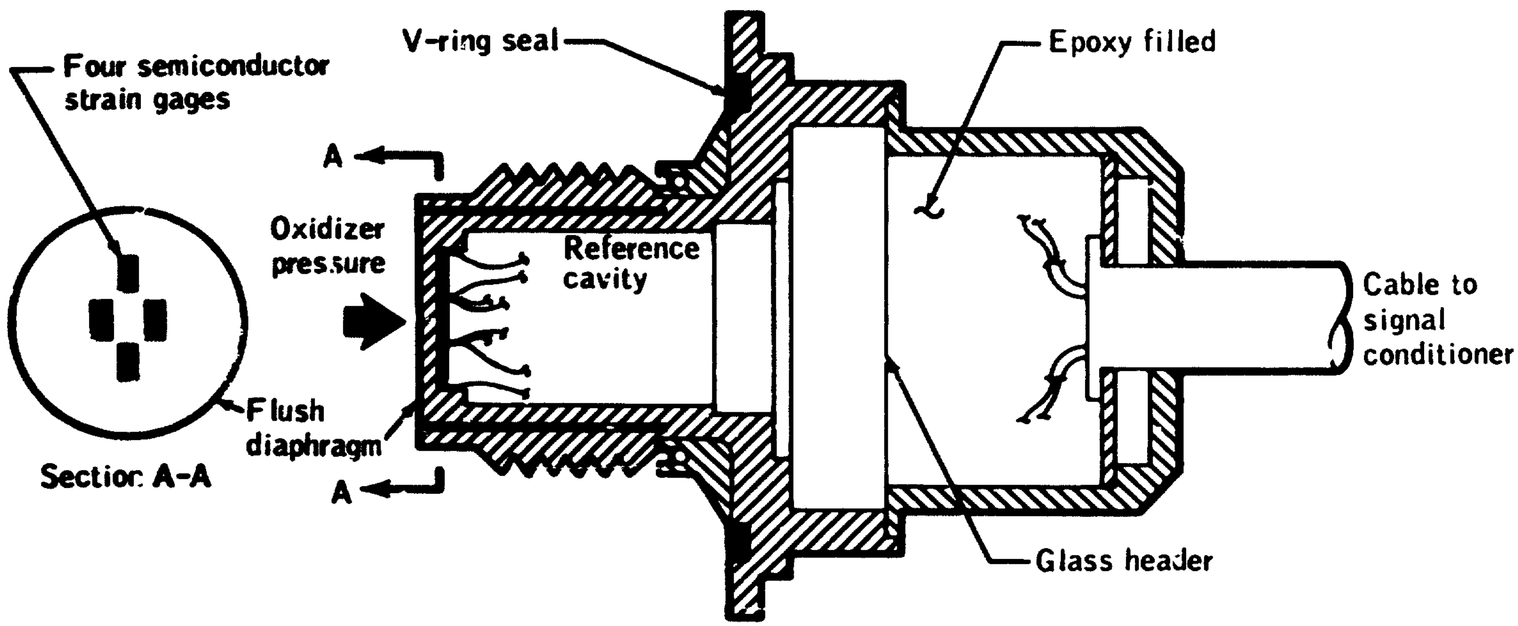


Figure 17-15.- Cutaway view of oxidizer pressure transducer.

Analysis shows that the failure must have been in the transducer. Similar malfunctions in the past were caused by separation of a strain gage from the diaphragm because of the failure of the cement. This failure causes a change in the transfer function between the pressure and the output voltage.

If this measurement should fail on a future mission, other measurements may be used to determine the service propulsion system performance.

This anomaly is closed.

17.1.8 Carbon Dioxide Partial Pressure Sensor Failed

The command module carbon dioxide partial pressure sensor indicated a value of 0.017 newton per square centimeter prior to crew ingress for launch. The indicated value remained constant throughout the mission, except for a 2-second period on visit day 2 when the indicated value jumped to 0.142 newton per square centimeter and tripped the master alarm.

Prior to crew ingress, the suit circuit was purged with oxygen and the sensor should have read approximately zero. After ingress, the reading should have increased to about 0.013 newton per square centimeter (3 percent of full scale).

The carbon dioxide sensor, a single-beam, dual-wavelength-filter photometer, is shown schematically in figure 17-16. Sample gas (fig. 17-17) flows through the optical system chamber.

The dual filter, which has the characteristics shown in figure 17-18, is mounted on one tine of a tuning fork and located at a point in the optical system near the focus plane of the source image. As the fork vibrates, the dual filter is moved back and forth across the light beam. There is also an opaque area in the center of the dual filter through which no energy passes. One side of the filter passes energy at 4.0 millimeters and the other side passes energy at 4.27 millimeters. Carbon dioxide absorbs energy at 4.27 millimeters and does not at 4.0 millimeters. The detector signal has the appearence shown in figure 17-16.

With no carbon dioxide in the sample, the sample signal amplitude is the same as the reference signal amplitude. With an increasing amount of carbon dioxide in the sample, the sample signal amplitude decreases in amplitude relative to the reference signal amplitude. Thus, the essential information for measuring the amount of carbon dioxide in the sample is present in the detector signal. An electronic system decodes the detector signal, and supplies an output voltage proportional to the partial pressure of carbon dioxide in the sample gas.

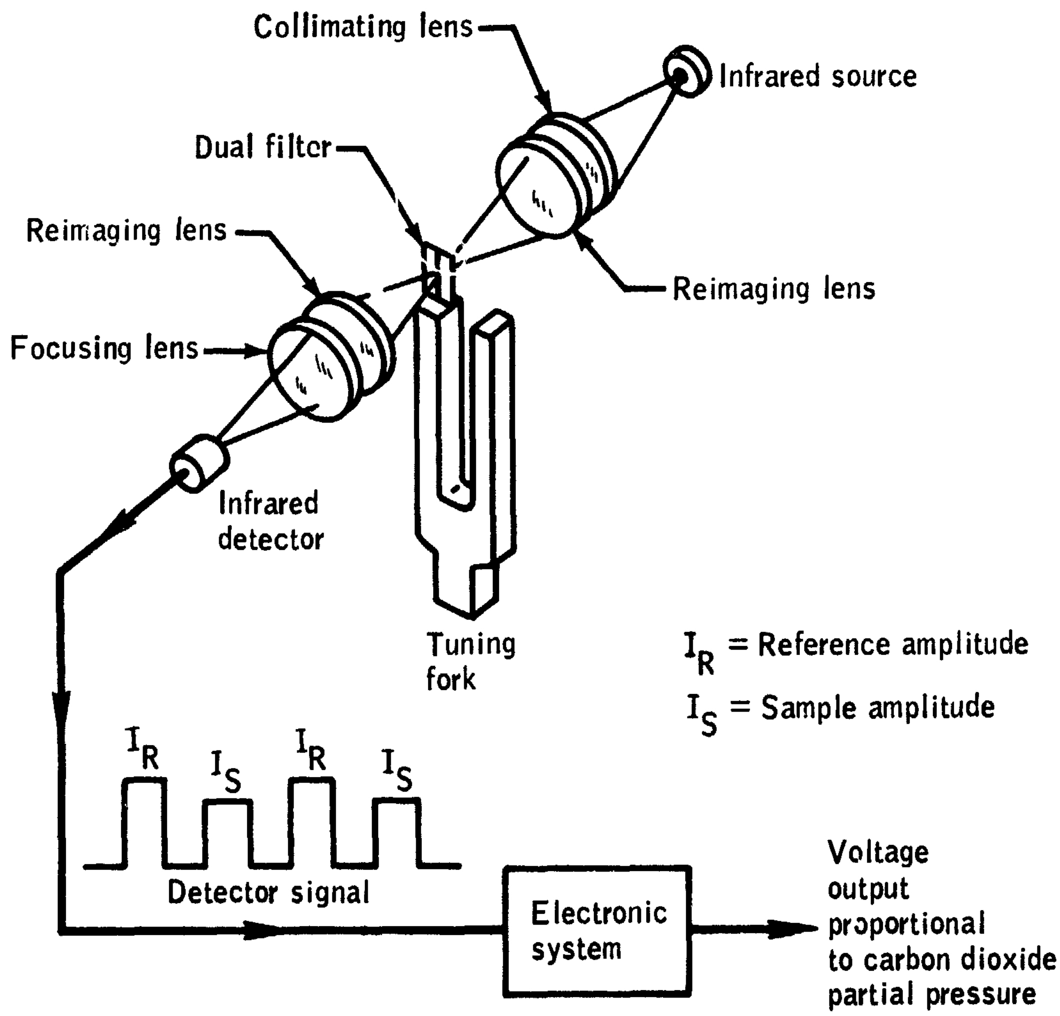


Figure 17-16.- Carbon dioxide sensor simplified system diagram.

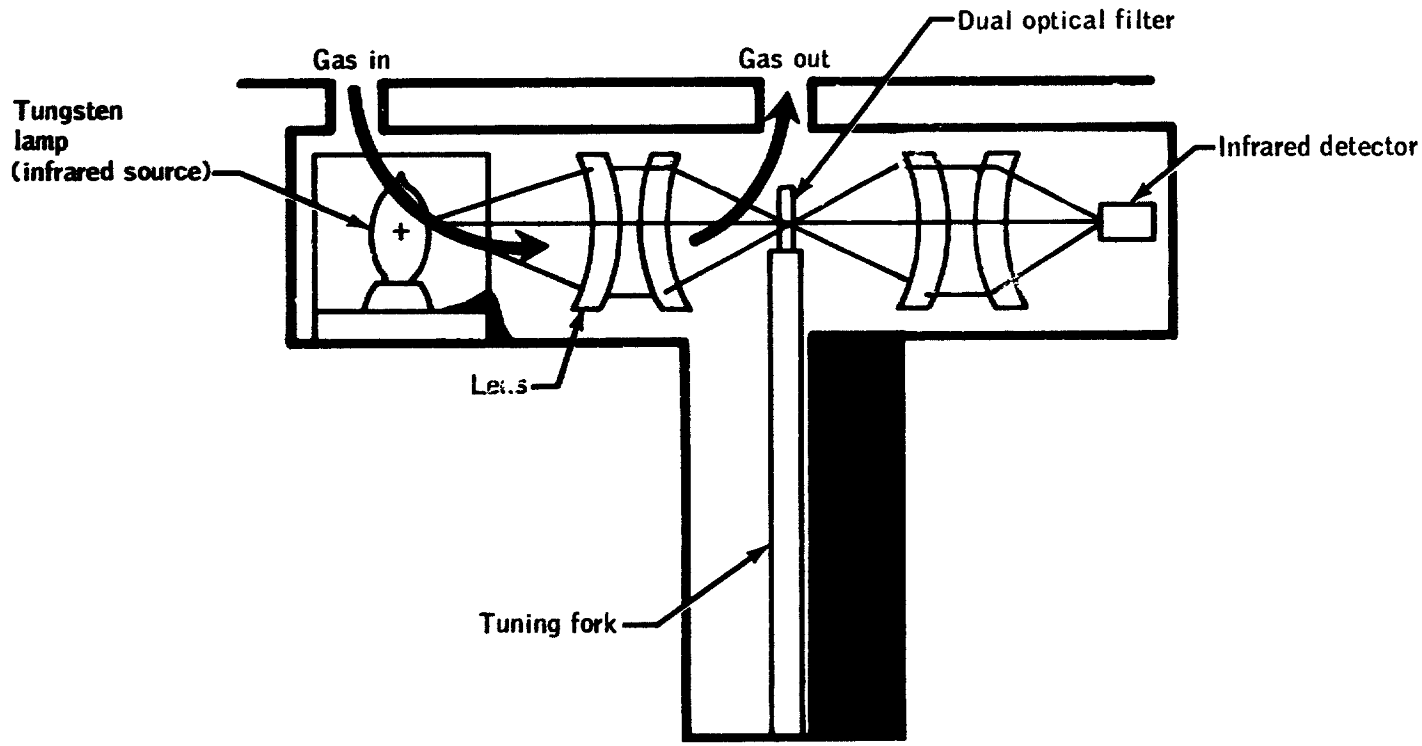


Figure 17-17.- Carbon dioxide partial pressure transducer.

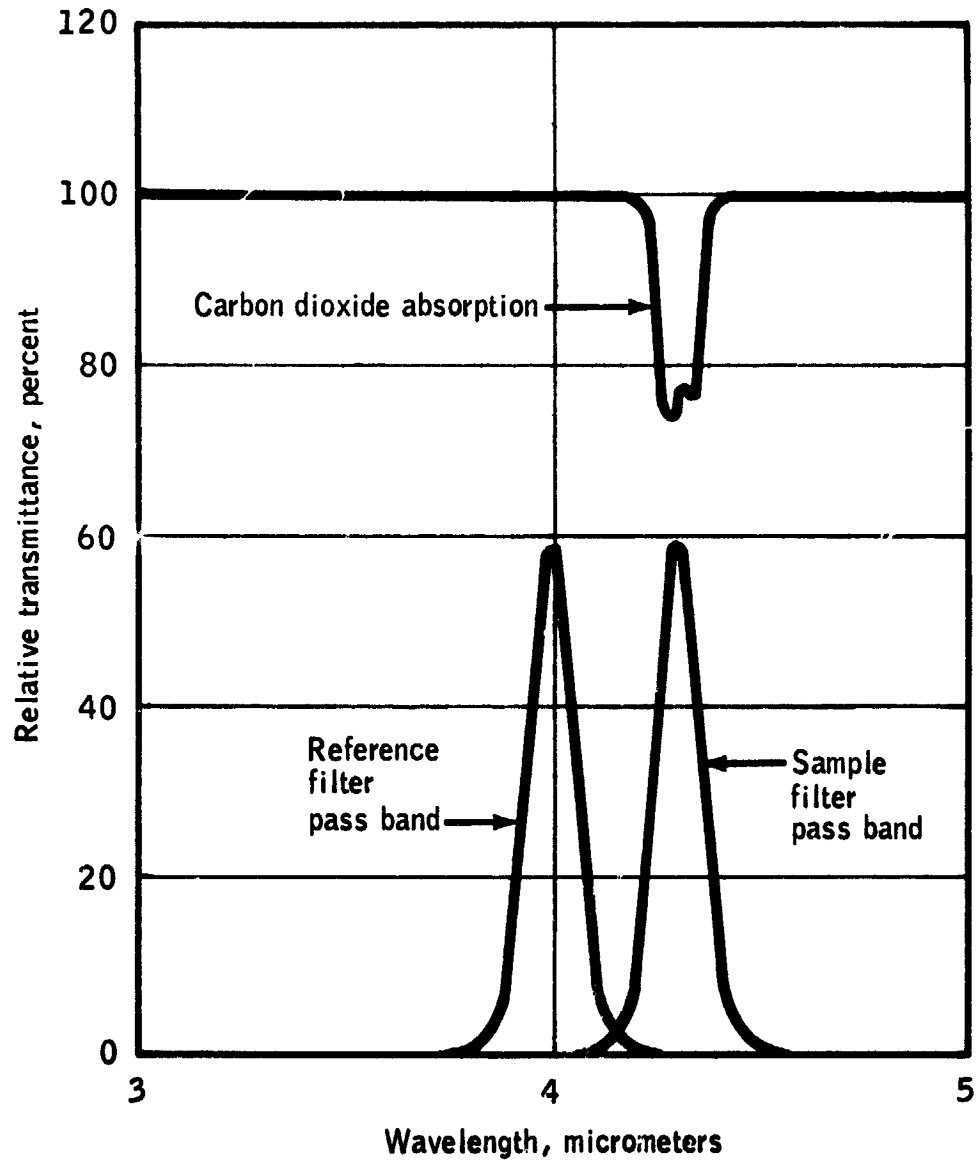


Figure 17-18.- Dual wavelength filter characteristics.

The carbon dioxide transducer is located in the left-hand equipment bay, above the environmental control unit (fig. 17-19). A water/glycol coolant line runs behind the unit. Previous failures similar to those noted in this transducer have occurred when the transducer was chilled below the dew point of the gas passing through the transducer, causing condensation within the transducer.

The carbon dioxide partial pressure measurement is not required for flight because the lithium hydroxide elements are changed based on time. Therefore, no action will be taken.

This anomaly is closed.

17.1.9 Command Module Reaction Control System Helium Manifold Pressure Measurement Erratic

The system 2 helium manifold pressure measurement exhibited downward shifts amounting to 2.41 to 3.45 newtons per square centimeter accompanied by apparent small pressure oscillations and then recovered. This occurred 15 times during the visit. At other times, the measurement appeared normal.

The transducer is a semiconductor strain gage resistance bridge mounted on a diaphragm. The bridge is connected to the signal conditioner by a four-conductor shielded cable 5 meters long.

Postflight tests showed that electrical noise introduced into the cable will cause the signal conditioner to shift downward and oscillate with the same characteristics observed in the flight data. During the Apollo 17 mission, the service module interface fuel pressure measurement had a similar anomaly. The signal oscillated because of an electrical transient condition caused by service propulsion engine operation.

The apparent pressure oscillations were caused by electrical noise that could have been coupled into the cable from currents flowing in the command module structure, since the command module single point ground was the single point ground for the total Skylab cluster at the time of the anomaly. The noise may also have been coupled by electromagnetic radiation from a source within the Workshop.

The noise only degrades the data slightly. Consequently, measurement system is satisfactory for flight.

This anomaly is closed.

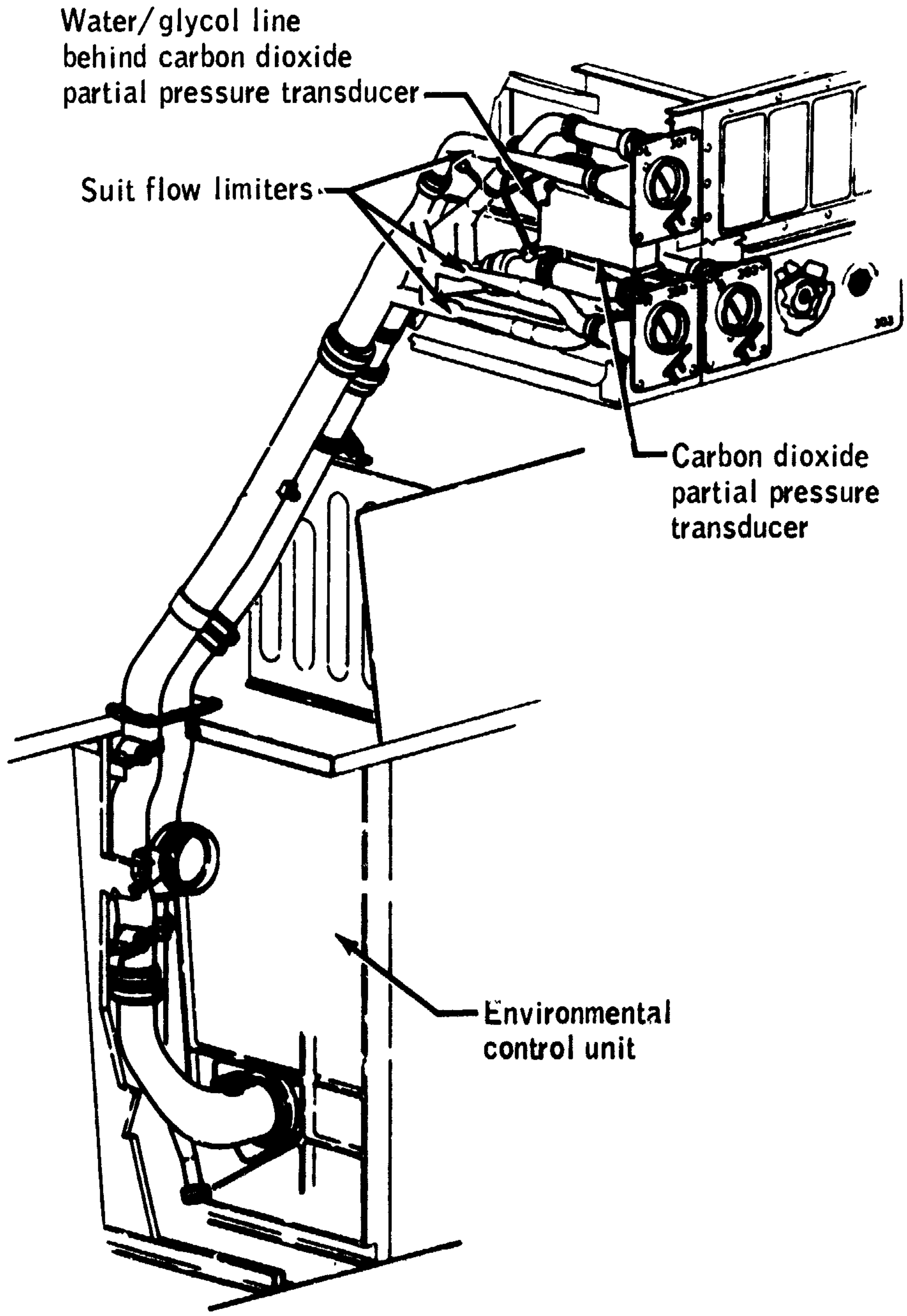


Figure 17-19.- Carbon dioxide partial pressure transducer location in left-hand equipment bay.

17.1.10 Audio System Noise

Noise was reported on the audio communications system immediately following the last extravehicular activity of the second visit. This noise was audible only on channel B and was described as a "pumping" sound with a frequency of about 4 hertz. The noise became audible when the volume level was raised to compensate for the unexpected 50-percent drop in signal level.

The channel B system permits uplink and downlink S-band and VHF communications, as well as audio intercommunications operation through headphones or speakers. An audio load compensator circuit allows variable impedance loading of the audio system while maintaining a nearly constant volume output.

At the time the noise was first detected, ground control personnel requested that the buffer-amplifier-1 and buffer-amplifier-2 circuit breakers be cycled in an attempt to isolate the noise source. The two parallel amplifiers of the audio lead compensator circuit are each powered through separate circuit breakers for redundancy. Opening of the buffer-amplifier-1 circuit breaker stopped the noise, whereas the noise continued when the buffer-amplifier-2 circuit breaker was opened. After discussions with ground control personnel, the crew elected to keep both circuit breakers closed because the noise was not too irritating for reasonable audio operation. About 6-1/2 hours after the problem occurred, the volume level of channel B jumped to normal, the volume control setting was returned to the normal setting, and the 4-hertz noise had disappeared.

One other isolated report of this 4-hertz noise occurred in the command and service module after the Pilot disconnected the Orbital Workshop/command and service module communications umbilical while the Pilot's headset was connected to the Pilot's audio center panel 6, which corresponds to Orbital Workshop channel A. Neither of the other two crewmen could hear the noise; however the Commander was connected to audio center panel 9, which corresponds to Orbital Workshop channel B, the previously reported noisy channel.

The close correlation between the loss of volume level and the 4-hertz noise indicates that the noise (amplitude modulation of background noise) is always present, but is below the threshold of audibility. However, when the volume level was increased to compensate for the approximate 50-percent drop in signal level, the 4-hertz noise became audible. The cause of the 50-percent drop in signal volume has not been determined, but some possible causes are:

a. Excessive loading of the earphone-speaker bus with an intermittent load that later cleared or was removed.

b. Erratic behavior of the automatic volume control feature of the audio compensator circuit of the Orbital Workshop.

c. Intermittent operation of the command module audio center.

The 4-hertz noise was not detectable on the delayed time voice tapes, which were telemetered during the flight, nor during a postflight playback of the command and service module onboard tapes. Postflight testing of the command and service module audio system failed to reproduce the noise. Further investigation of this problem will not be conducted because the noise, when present, was only a nuisance to the crew and the conditions under which the noise exceeded the audible threshold were unique to the second visit.

This anomaly is closed.

17.2 EXPERIMENT ANOMALIES

17.2.1 Experiment S071/S072 Failure

All telemetry data from experiments S071/S072 (Circadium Rhythm of Pocket Mice and Vinegar Gnats) ceased at 18:58:36 G.m.t. on visit day 2.

The equipment for these two experiments consists of a complete environmental system for the pocket mice and vinegar gnats, plus sensors and telemetry. Electrical power is supplied through two parallel branches. Each branch contains a 15-ampere fuse, an input power filter, and a steering diode (fig. 17-20), and is capable of supplying the normal operating current of 5 amperes. The 28-volt power is fed to the glycol pump power inverter and the voltage regulator network.

Three seconds before all telemetry from the two experiments ceased, the command and service module main bus current surged to 63.6 amperes from an average load of 23.3 amperes. The current surged erratically for 1 minute and 51 seconds. This was followed by a 53-second period of normal load after which the excursions resumed and continued for 1 minute and 13 seconds. At that time, the bus currents returned to normal levels. Later, cycling of the power switch to this experiment produced no detectable change in current load on the command and service module buses, indicating that the experiments were no longer drawing current. At that time, the power was shut off to the experiment.

The electrical short causing the power failure could not have occurred on the bus side of diodes CR1 and CR2. A short to ground in either branch would have blown the fuse protecting that branch. Normal power of 5 amperes would then be supplied through the remaining branch.

Analysis and ground tests were conducted using the pump inverter modules of the backup units. These units and the flight units had been procured as off-the-shelf hardware. Inspection revealed that arcing had occurred through the potting material because terminal posts were located too close to the case. Deliberately shorting phases of the inverter circuit to each other, or to ground, produced the same characteristics as seen in the flight data.

Poor packaging and wire routing are believed to be the cause of this failure. Ames Research Center will publish the detailed results of this failure. The experiments are not scheduled for the remainder of the Skylab program. Therefore, no corrective action is required.

This anomaly is closed.

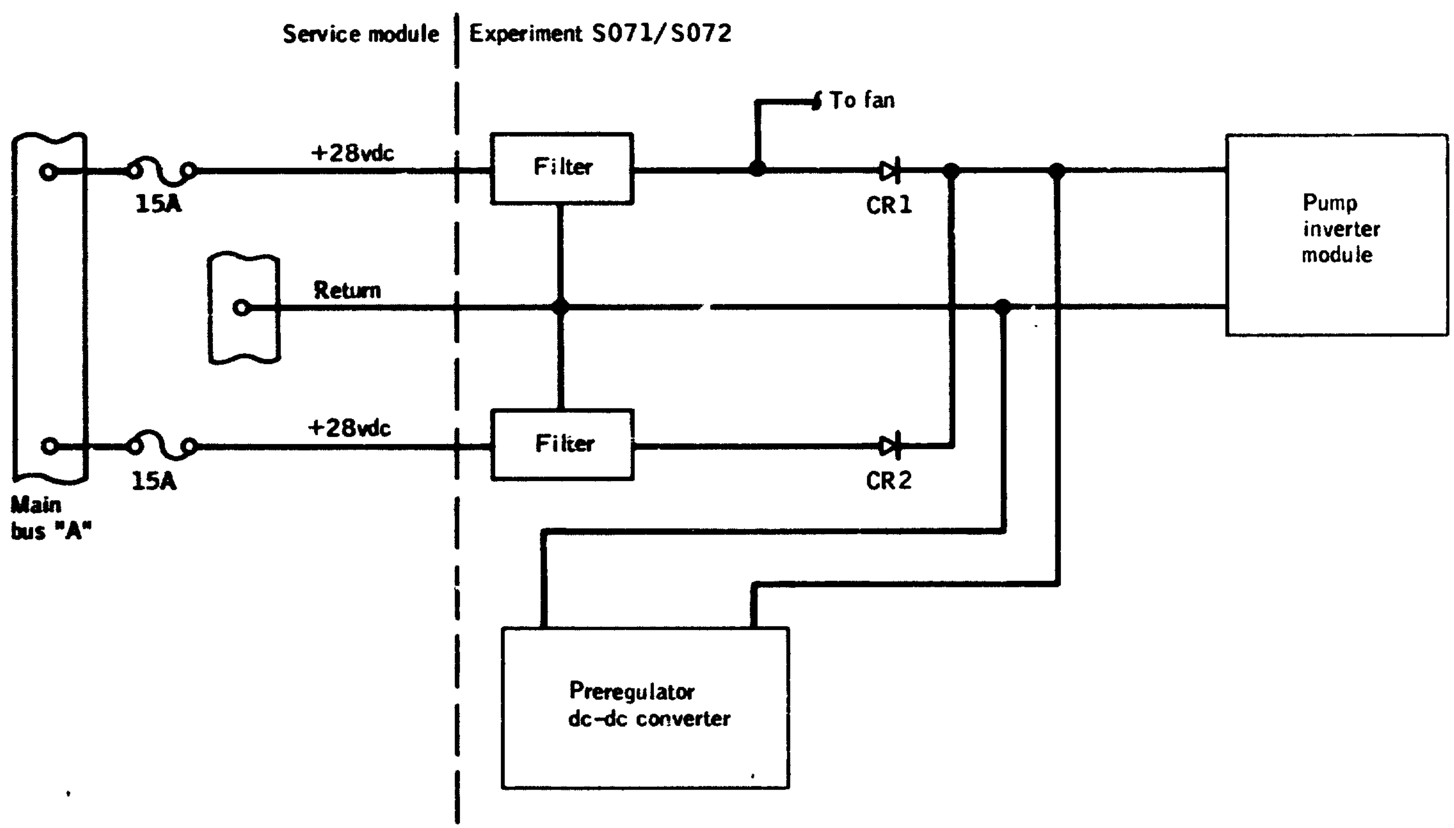


Figure 17-20.- Experiment S071/S072 power distribution and conditioning.

17.2.2 Experiment M092 - Limb Volume Measurement System

The limb volume measurement system could not be calibrated using leg band assembly BJ.

The left leg band gain circuit could not be adjusted to drive the left leg volume meter during the calibration procedure on visit day 6. The problem was isolated to the leg band assembly unit BJ by replacing it with another leg band which operated properly.

The leg band assembly (fig. 17-21) measures leg volume changes by measuring the calf circumference change. The flexible leg band assembly contains two circumferential electrically conducting strips separated by a spongy dielectric plastic (fig. 17-22). The inner strip also has spongy dielectric on its underside to electrically isolate the subject's leg. The inner strip and the subject's leg form the two plates of a capacitor and the outer strip acts as the electrostatic shield. The assembly also contains two conductive strips that act as a calibration capacitor, and a relay circuit module that switches the calibration capacitor into the circuit when performing gain calibrations.

As the subject's leg volume increases, the sponge along the undersurface of the leg band assembly is compressed. As a result, the annular distance between the leg and the inner circumferential strip decreases, and a corresponding increase of capacitance occurs.

A 100-kilohertz signal is supplied to the leg band as shown in figure 17-23. The leg band capacitance bypasses part of the 100-kilohertz signal to the leg which is grounded. The remaining current is the leg band signal output, which is diode rectified and supplied to the signal conditioner.

A matching network in the signal conditioner (fig. 17-24) converts the leg band output signal to a voltage that is proportional to the leg volume change. This voltage is amplified and supplied to a leg volume display meter and to telemetry.

The matching network contains a voltage reference that is manually adjusted to null the leg volume meter. After nulling the meter, the calibration capacitor is switched into the circuit, and this increases the leg band capacitance to a specified value. The matching network gain is manually adjusted to drive the leg volume meter to the specified value. The calibration capacitor is switched out of the circuit after which the system is ready for use.

At the time the failure was noted, the left leg band measurement circuit had been nulled to zero, but the gain could not be adjusted.

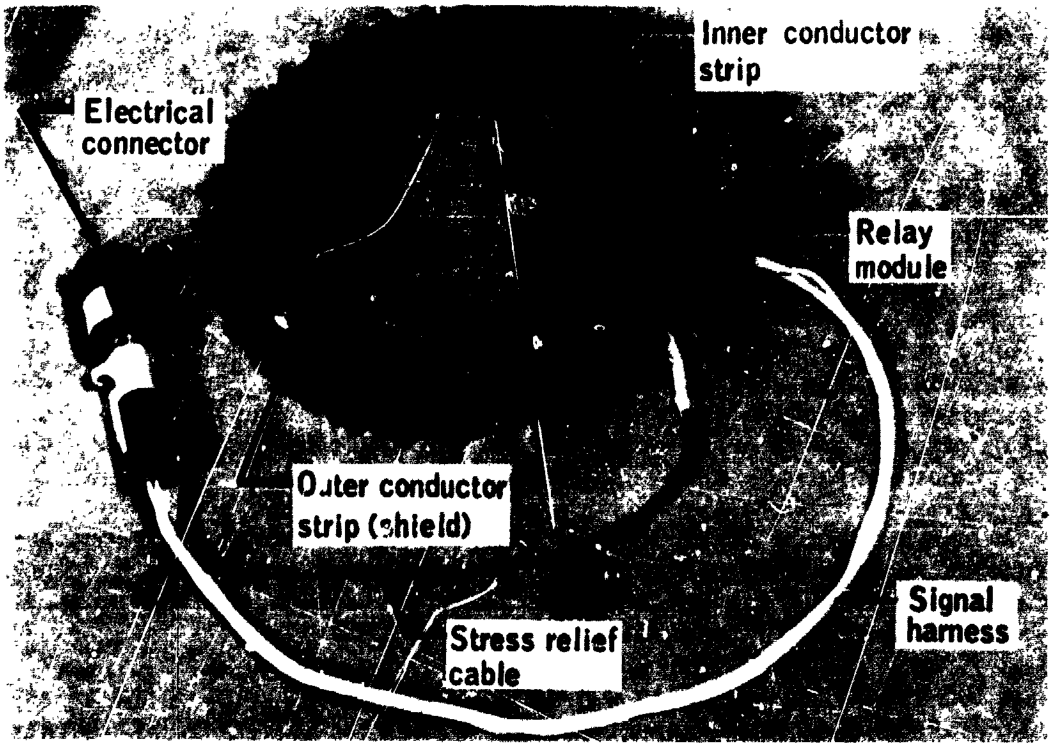


Figure 17-21.- Leg transducer.

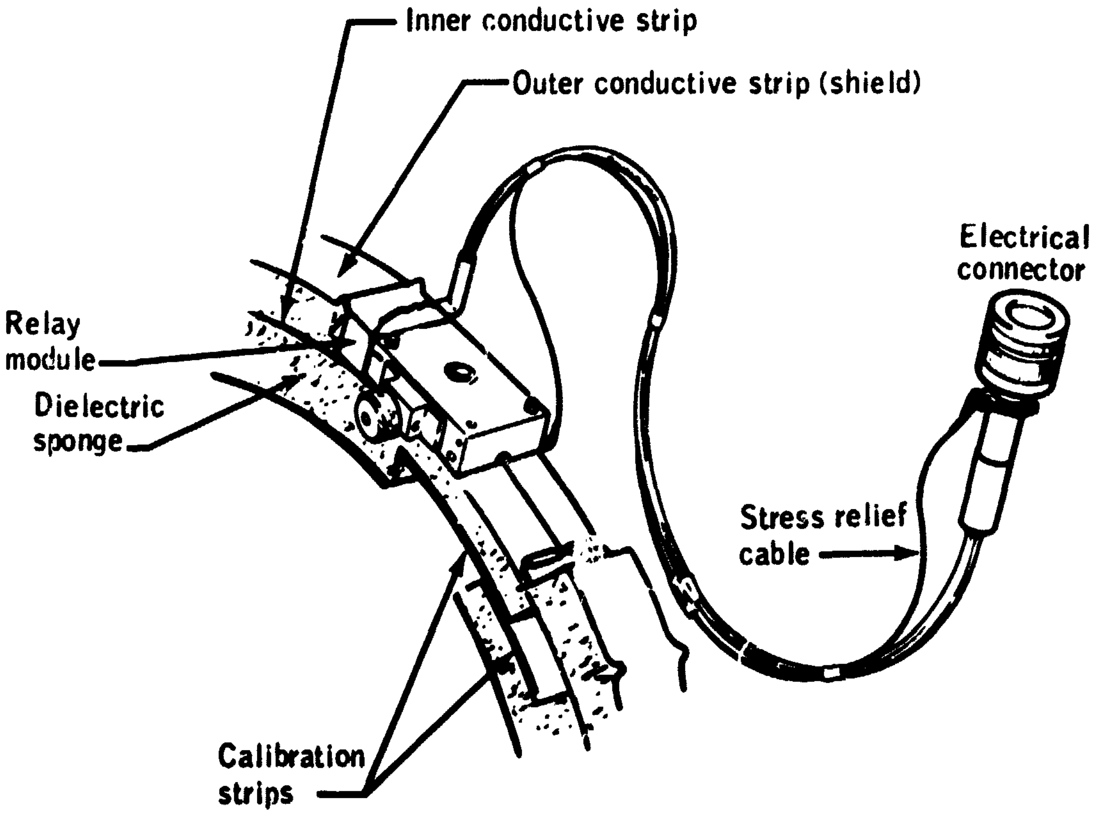


Figure 17-22.- Cross section of leg band assembly.

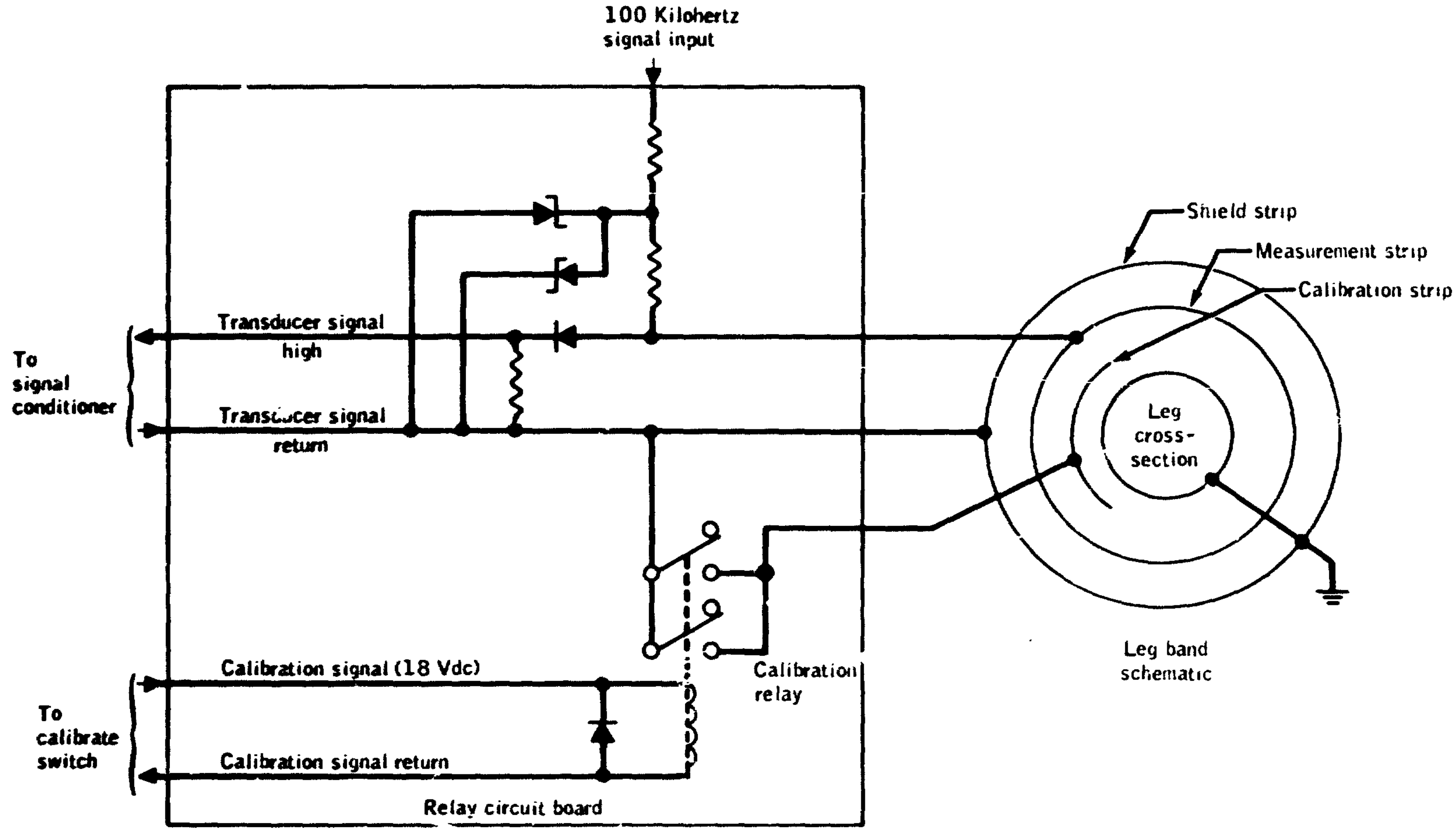


Figure 17-23.- Schematic of leg band circuit.

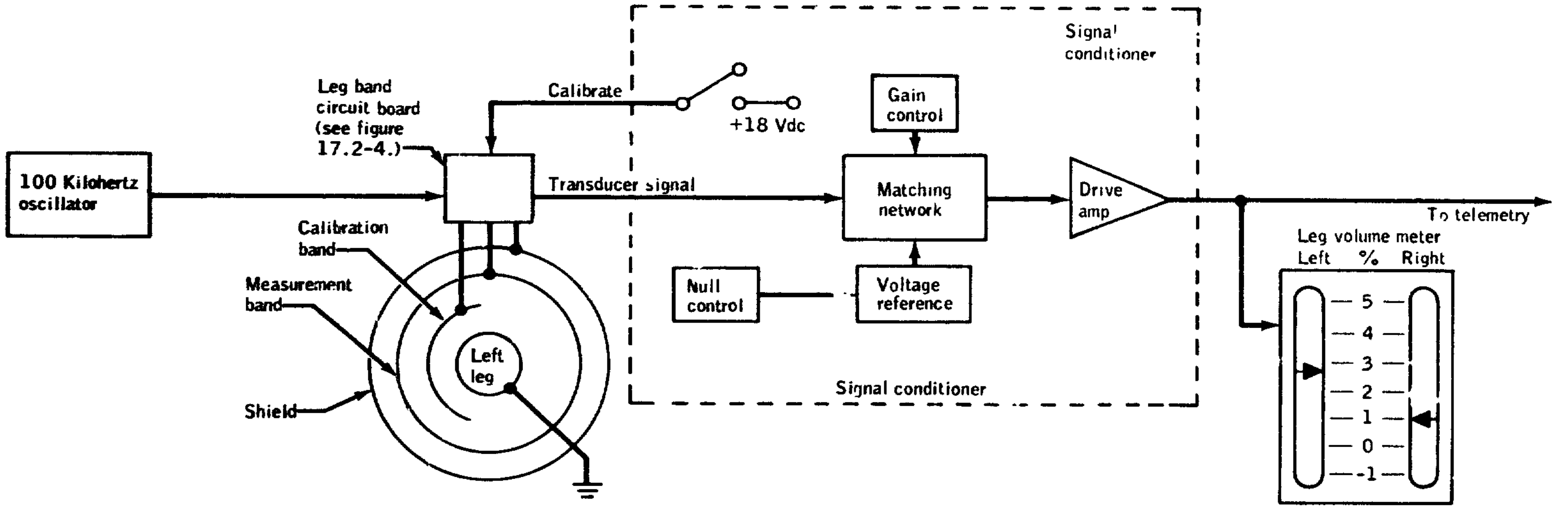


Figure 17-24.- Simplified block diagram of the leg volume measurement system.

The left leg band was replaced and the calibration procedure was performed successfully.

Seven and one-half hours later, when performing the experiment on another subject, leg band assembly BJ exhibited the same calibration failure. The leg band was again replaced and a successful calibration was performed.

Postflight testing of leg band assembly BJ has not reproduced the flight failure. The cause of the anomaly is unknown.

There are five leg bands of this size remaining on board. This quantity is sufficient to complete the mission. Therefore, no corrective action will be taken.

This anomaly is closed.

17.2.3 Experiment S191 (Infrared Spectrometer) Door Operation

The normal opening or closing time of the door is about 2 minutes. The door operation became slow and erratic during the fifth Earth Resources Experiment Package pass on visit day 12. Figure 17-25 shows the door and figure 17-26 plots the actuation time of the door, beginning with that event. The closing time of the door for the seventh Earth Resources Experiment Package pass shows a step increase above the normal time. From that event until the end of the second visit, there was no significant increase in door operation time. The times for the seventh and eighth pass and the final closing show that the door situation, although not normal, was consistent.

The experiment S191 spectrometer and optics assembly are mounted externally on the Multiple Docking Adapter. The optics assembly is protected from contamination when not in use by the door. The door also assists in controlling the experiment equipment temperatures. The mechanical motive force for door operation is provided by a stepper motor through the gear train shown in figure 17-27. The motor is housed and mounted inside the experiment mirror assembly. The normal motor speed is 1500 revolutions per minute which is reduced to 0.02 radian per second at the door hinge shaft.

Figure 17-28 shows one of four circuits that drive the four sets of field coils of the motor. The four coil sets are pulsed sequentially with the 50-hertz square wave driving voltage to provide a rotating magnetic field. The coil sets are arranged such that [illegible] cycles of the 50-hertz voltage produce one rotation of the field flux, giving rotational speed of 1500 revolutions per minute. The motor, therefore, runs at a

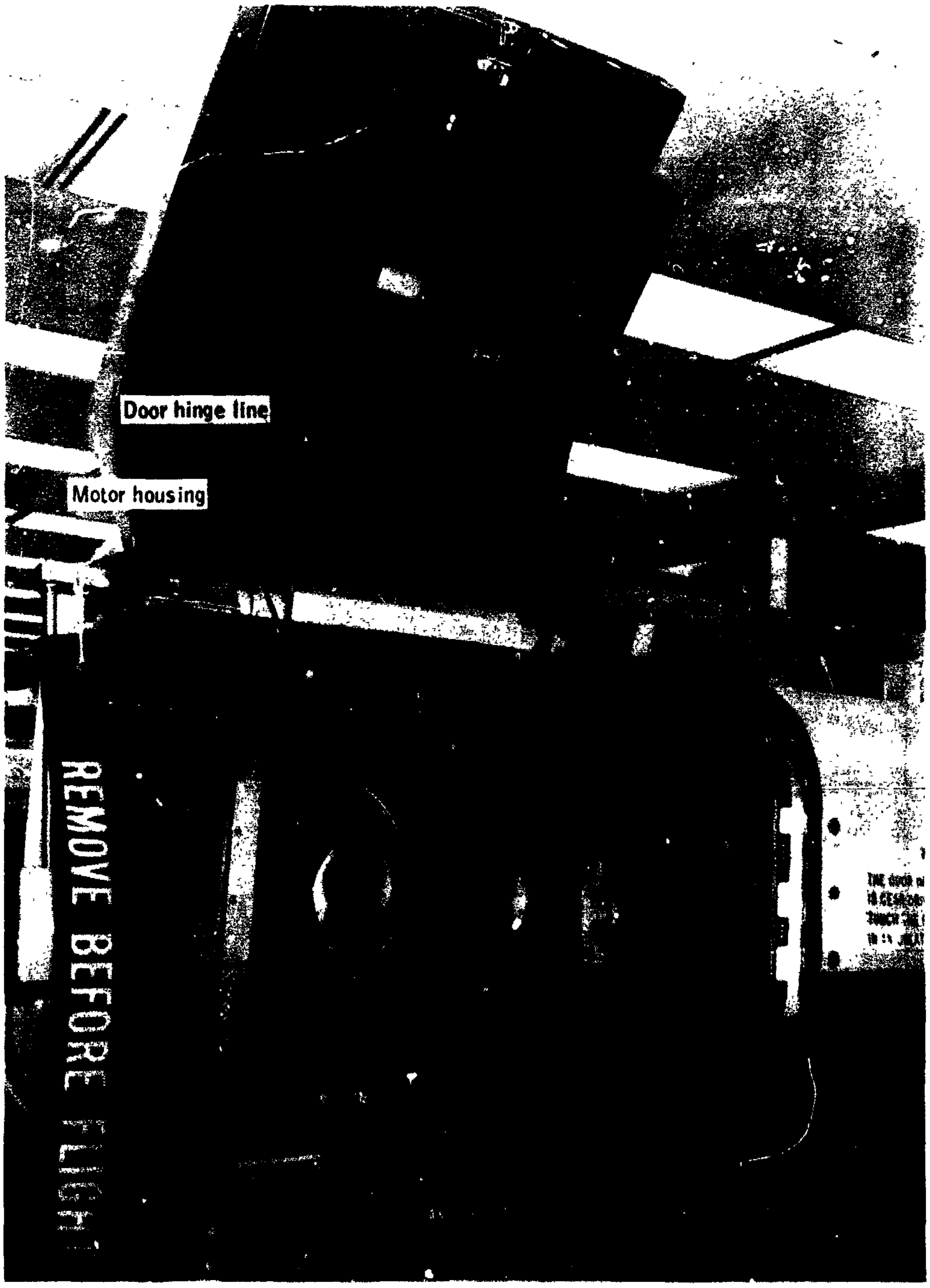


Figure 17-25.- Experiment S191 door assembly.

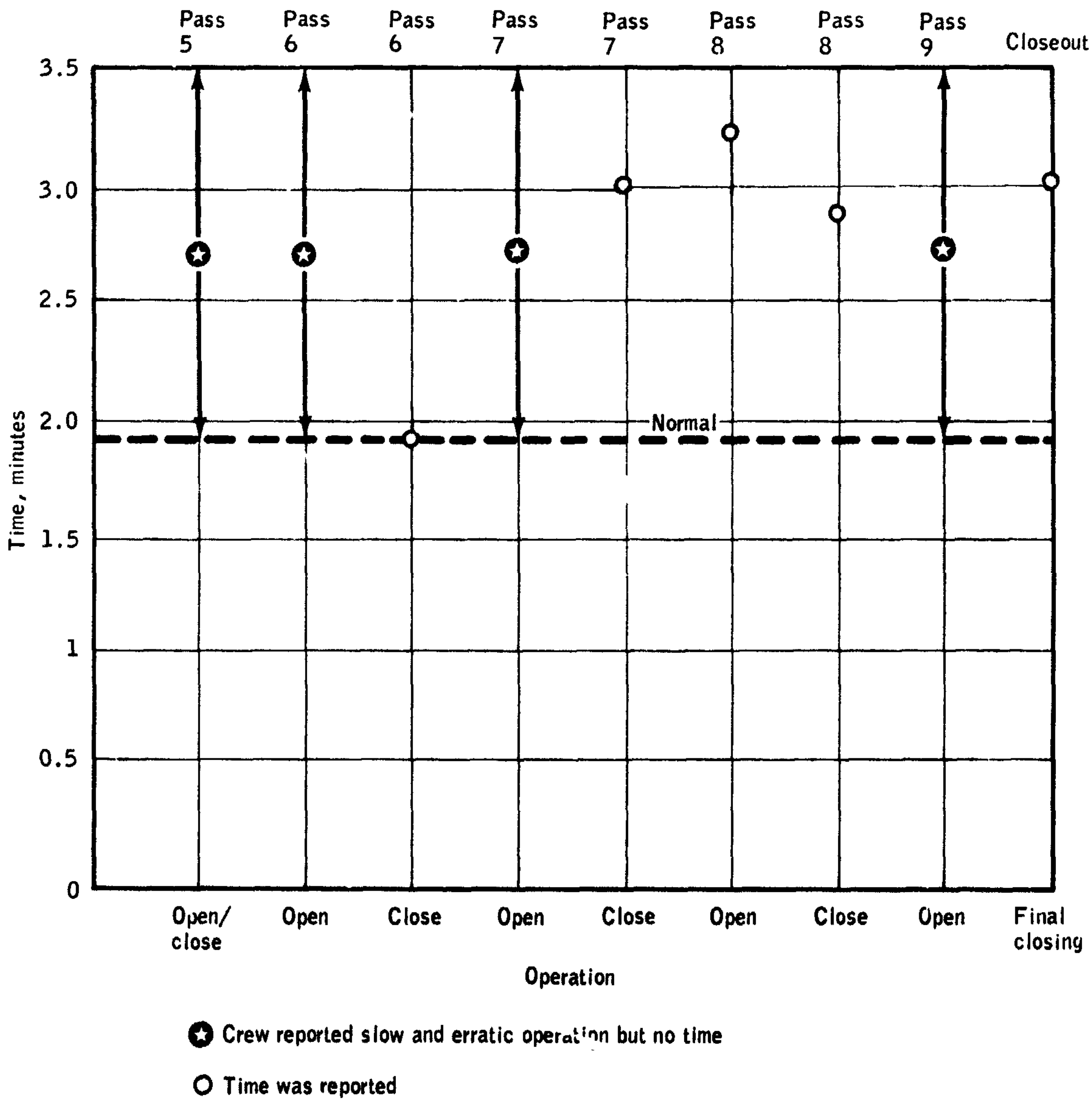


Figure 17-26.- Experiment S191 door actuation times.

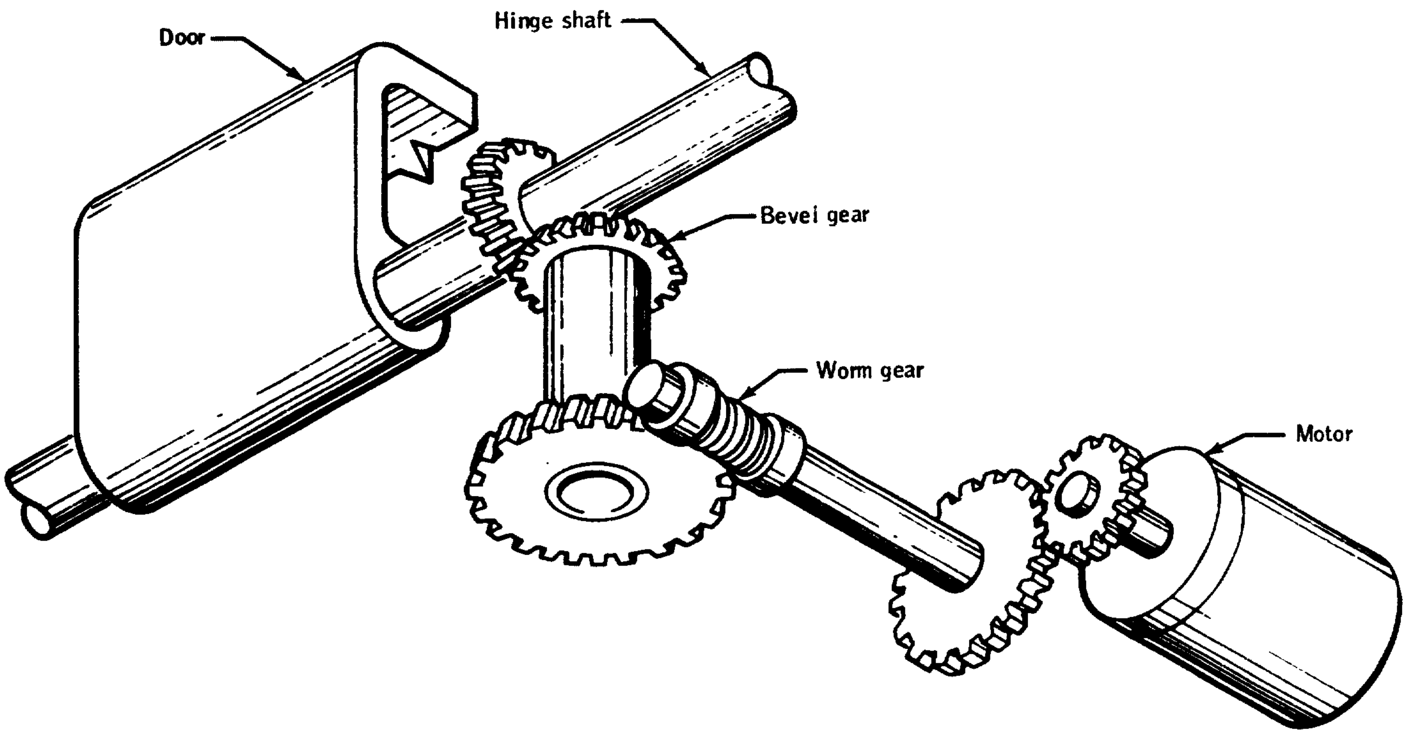


Figure 17-27.- Equipment S191 door motor and gear train.

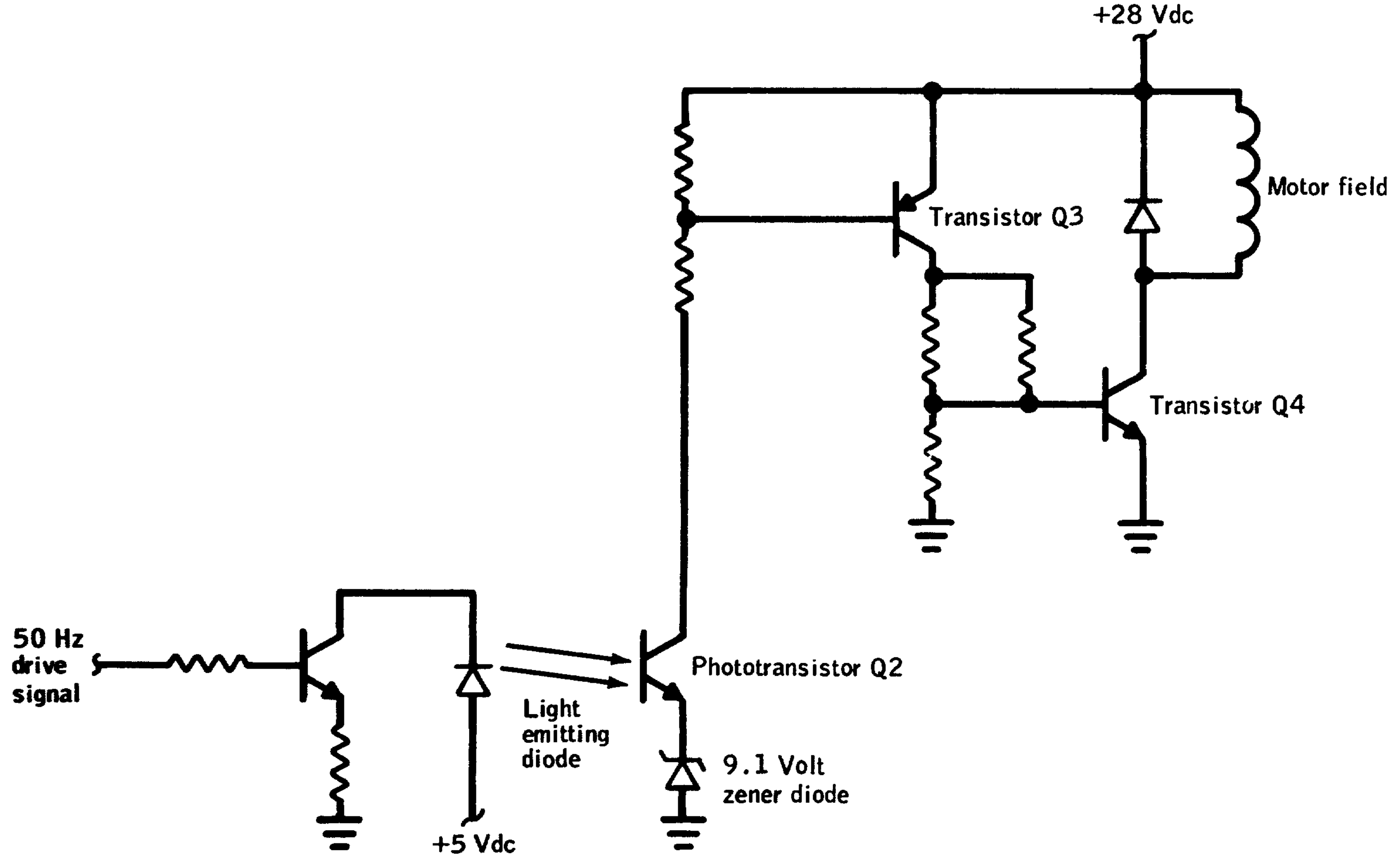


Figure 17-28.- Motor drive electronics.

synchronous speed, as long as the load is within the torque capacity of the motor. The motor drive circuit transistor Q1 is driven by the 50-hertz square wave voltage and, in turn, drives the light emitting diode which is optically coupled to phototransistor Q2. Phototransistor Q2 drives transistors Q3 and Q4. Transistor Q4 switches the 28-volt supply voltage to the field winding. A suppression diode is connected across the motor winding to damp ringing when the coil voltage is switched off.

Ground tests have shown two conditions that could cause the slow and erratic operation. The first condition is that the mechanical load increases to approximately the motor stall torque. This possibility can be discounted because the motor will run at synchronous speeds until the load is near the stall torque. It is unlikely that the load would increase to that level and no further. The second condition is interruption of the drive voltage to one of the motor windings. This possibility fits the flight indications since the speed did not continue to decrease with operating time.

Action will be taken to reduce the number of door actuations to a minimum. The door was closed prior to the departure of the second visit crew. The door will be opened after docking on the third visit and left open until the end of the mission to minimize the probability of door failure. General optical contamination as a result of this door being open is acceptable. Mission planning adjustments have been made to manage the thermal differences caused by operations with the door open.

This anomaly is closed.

17.2.4 Experiment S019 (Ultraviolet Spectrometer) Mechanism Jammed During Retraction

The articulated mirror assembly of experiment S019 failed to fully retract on visit day 24. The mirror retracted about 1/6 the required distance and stopped. After several attempts to re-extend and retract, the system jammed. However, on visit day 25, the system returned to normal operation.

The extend/retract mechanism is shown in figure 17-29. The motion of the eight sets of ball drive nuts and screws must be synchronized to allow movement and to assure accurate optical alignment during the travel of the assembly.

Before the visit day 24 extension, the assembly was opened to the cabin environment to install a prism. The usual 3-hour warmup period in the scientific airlock was not implemented. Moisture present in the cabin air condensed on the cold surfaces of the assembly and froze during the next extension, and possibly caused the jam. Sublimation of the ice should return the system to normal operation.

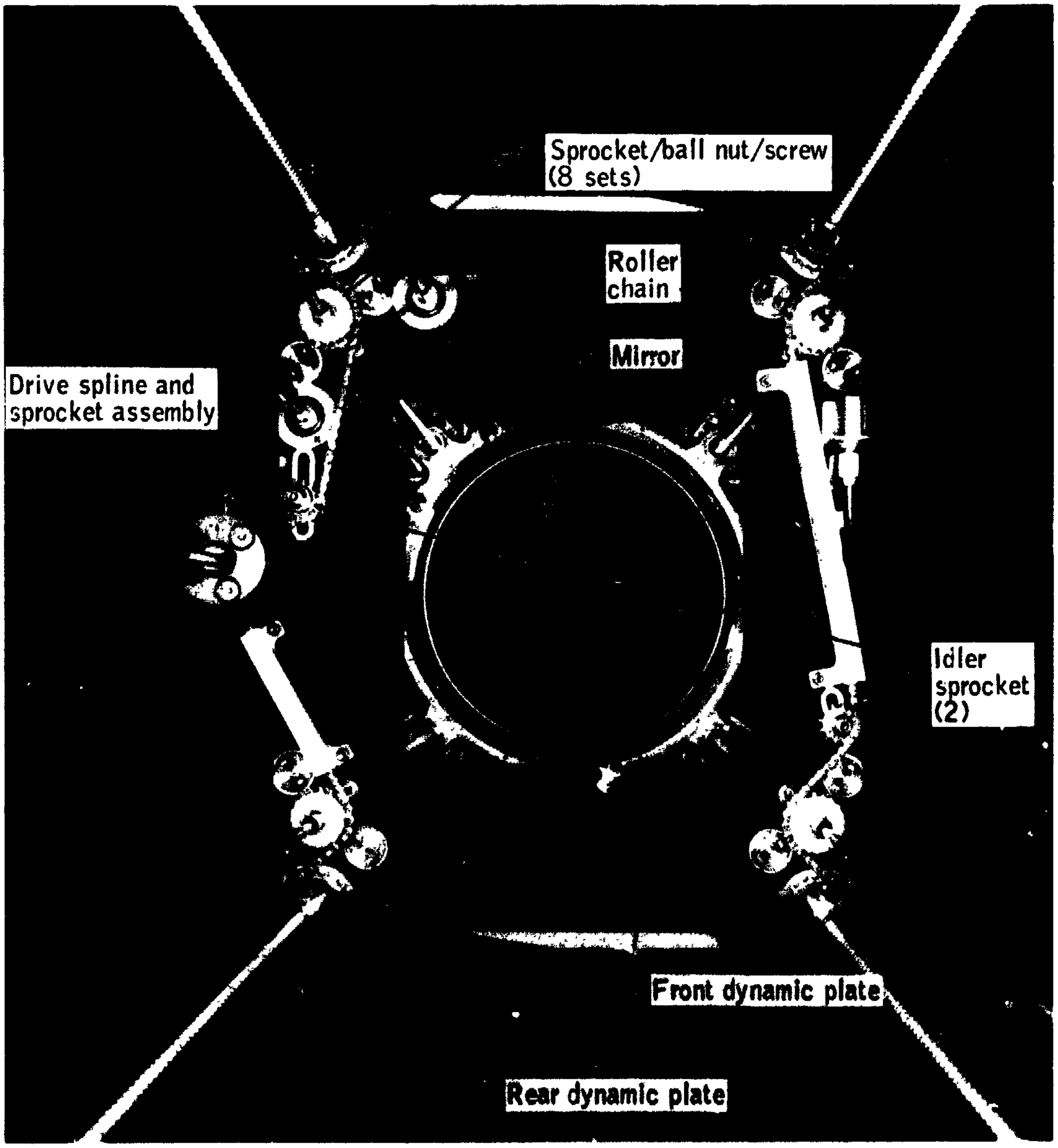


Figure 17-29.- S019 Articulated mirror assembly extend/retract mechanism.

The temporary jamming was, most likely, the result of ice forming on the mechanism when the usual warmup period was omitted. Warmup and dryout sequences will be observed for all remaining experiment operations.

This anomaly is closed.

17.2.5 Experiment S193 Antenna Failed to Scan

During Earth Resources Experiment Package pass 29, on visit day 49, the altimeter receiver and the scatterometer transmitter malfunction lights illuminated.

During pass 32, on visit day 50, while the crew was troubleshooting the previous malfunction, the scatterometer transmitter malfunction light again illuminated. The following parameters were all reading improperly: Pitch and roll gimbal angles; minus 10 volt supply; radiometer automatic gain control; pitch and roll command position; pitch and roll gimbal motor torquer currents; and pitch and roll on orbit align bias.

The antenna gimbal servo loop (fig. 17-30) uses both plus 10 Vdc and minus 10 Vdc regulated voltages to excite the ends of the servo feedback potentiometer. The regulated voltages are both derived from a 6.2-volt Zener diode. The Zener diode output is first amplified and then inverted, giving the regulated plus 10 Vdc. This voltage becomes the input for a unity gain inverter giving a regulated minus 10 Vdc output. The plus and minus regulated 10 Vdc outputs are then buffered by voltage followers before being used to excite the gimbal servo feedback potentiometers. This isolation is required to prevent the potentiometers from loading down the regulated outputs.

The regulated plus and minus 10 Vdc outputs are also used as reference voltages for the telemetry signal conditioners, control and display panel meter buffer amplifiers, and the antenna position command logic.

The measurement of the minus 10 volt supply indicated that the supply voltage was minus 0.99 volt. Ground tests have shown that if the output of the voltage follower supplying minus 10 volts to the servo potentiometers was shorted to ground, the voltage follower input voltage would be held at minus 0.99 volt and all of the improper indications (and no others) would result. The fault, therefore, must have been a short to ground somewhere on the output of the minus 10 Vdc voltage follower.

Data showed that the loss of the minus 10 Vdc on visit day 50 first occurred at the end of an antenna pitch retrace (plus 0.84 radian) and lasted for less than one data frame of 375 milliseconds. (The antenna sweeps from plus 0.84 radian to 0 radian taking data, and then retraces

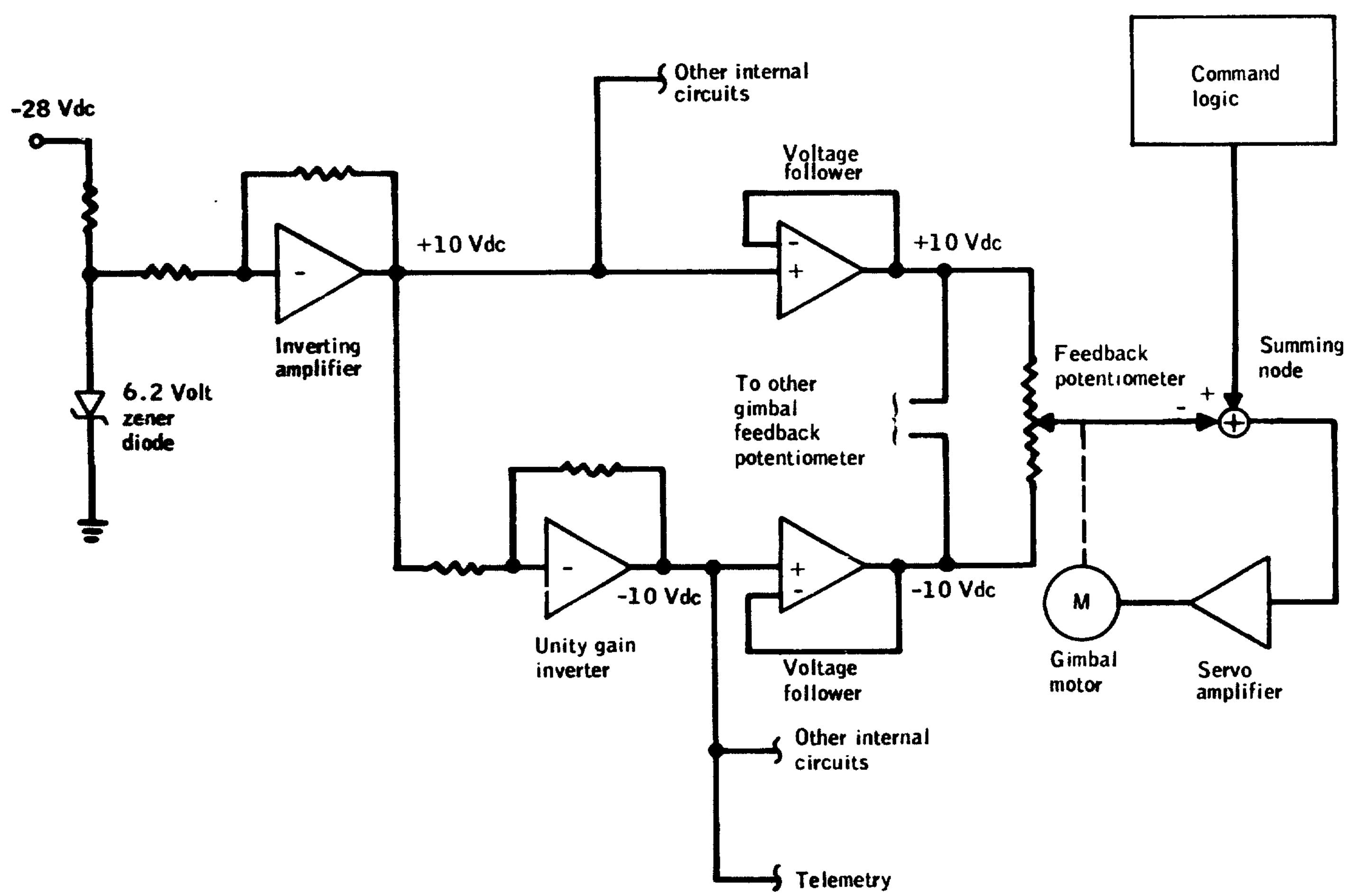


Figure 17-30.- Antenna gimbal servo loop.

to plus 0.84 radian for the next data-taking scan.) At the time, the roll gimbal was commanded to a fixed position (0 radian). The problem then cleared and the operation was normal through the next antenna data-taking scan. The fault again occurred at the end of the second antenna pitch retrace (plus 0.84 radian). Thereafter, the minus 10 volt output varied from minus 1 to minus 1.22 Vdc for a period of about 15 seconds and then steadied at a value of minus 0.99 Vdc. This operation is symptomatic of a mechanical-type short circuit somewhere in the antenna or its flexible harness, and not a component short circuit.

The antenna (fig. 17-31) is driven in two axes — pitch and roll. Each axis uses a feedback potentiometer to supply antenna position information to the gimbal servo loop as shown in figure 17-30. The potentiometer (fig. 17-32) consists of a 2.13-radian circular segment resistance element that is bonded to the antenna housing. The potentiometer wiper is attached to the axis shaft which turns within the housing. The resistance element is partially exposed and conductive contamination could have shorted the minus 10 Vdc end of the element to ground. In addition, since the excitation voltages are supplied to the resistance element by a twisted shielded pair cable, the shield termination ferrule may have cut through the minus 10 volt conductor insulation and grounded the conductor.

The following corrective actions are planned for the first extravehicular activity during the third visit. The feedback potentiometer resistance elements will be cleaned. If this does not restore normal operation, the antenna will be pinned in a fixed position.

This anomaly is closed.

17.2.6 Experiment S019 (Ultraviolet Stellar Astronomy) Film Canister Jammed

On visit day 56, the film advance/shutter control crank on film canister 005 jammed at the carriage-retracted position and would not continue to rotate on to the slide-retracted position. Therefore, a new slide could not be transferred into the carriage from the supply stack nor could the exposed slide be ejected into the takeup stack.

Film slides are mounted in the film canister in two stacks of 81 slides, each on either side of the carriage (fig. 17-33). In addition, a slide is in the carriage, and a slide is in an intermediate position in the rear of the canister. After the slide in the carriage is exposed, the carriage is retracted from the optical focal plane and this action aligns the opening in the carriage slide guide with the stationary slide guides. An unexposed slide from the supply stack is then transferred into the carriage and the exposed slide is ejected into the takeup stack. At the same time, a similar transfer takes place at the rear of the canister.

Figure 17-31.- Experiment S193 antenna.

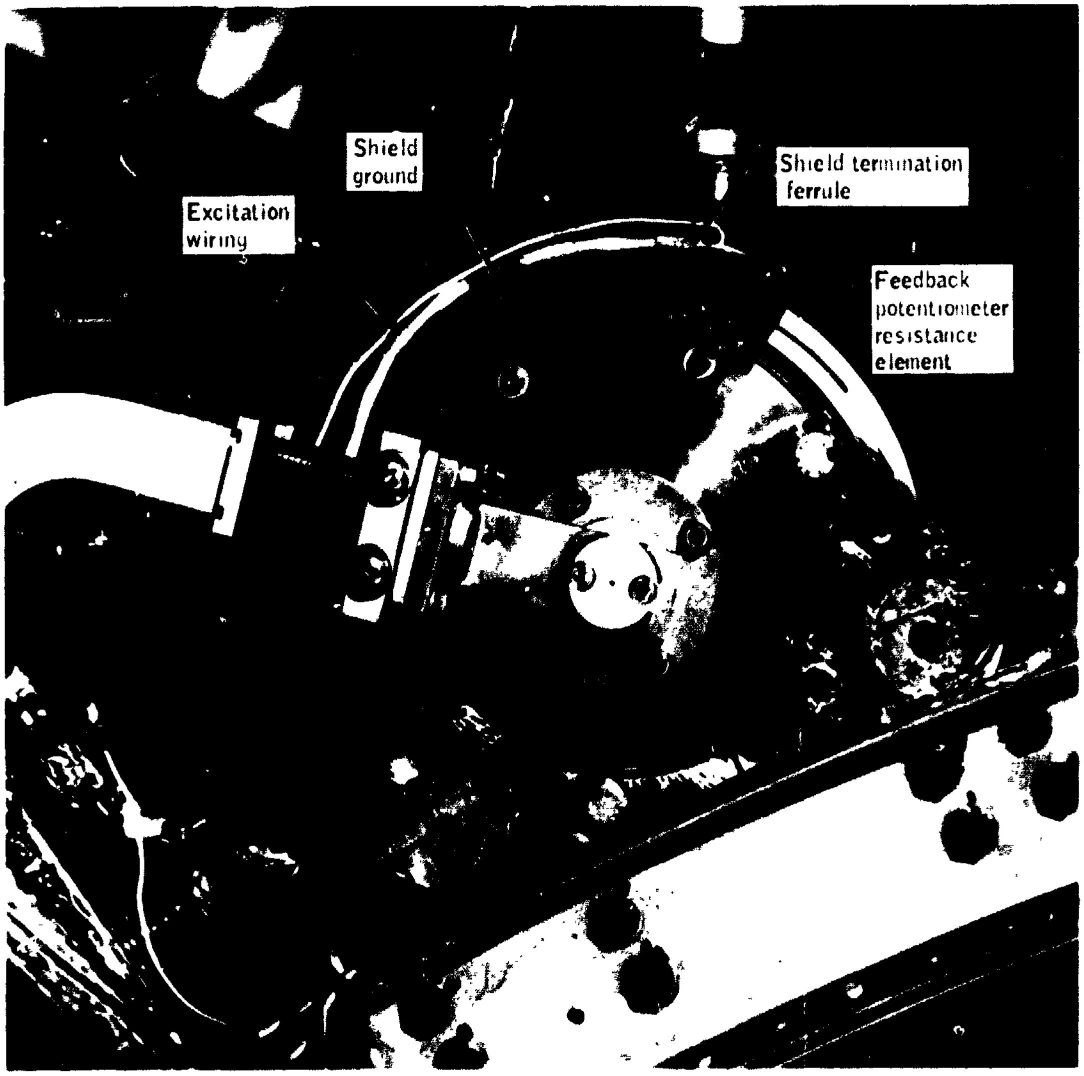


Figure 17-32.- Experiment S193 antenna pitch gimbal.

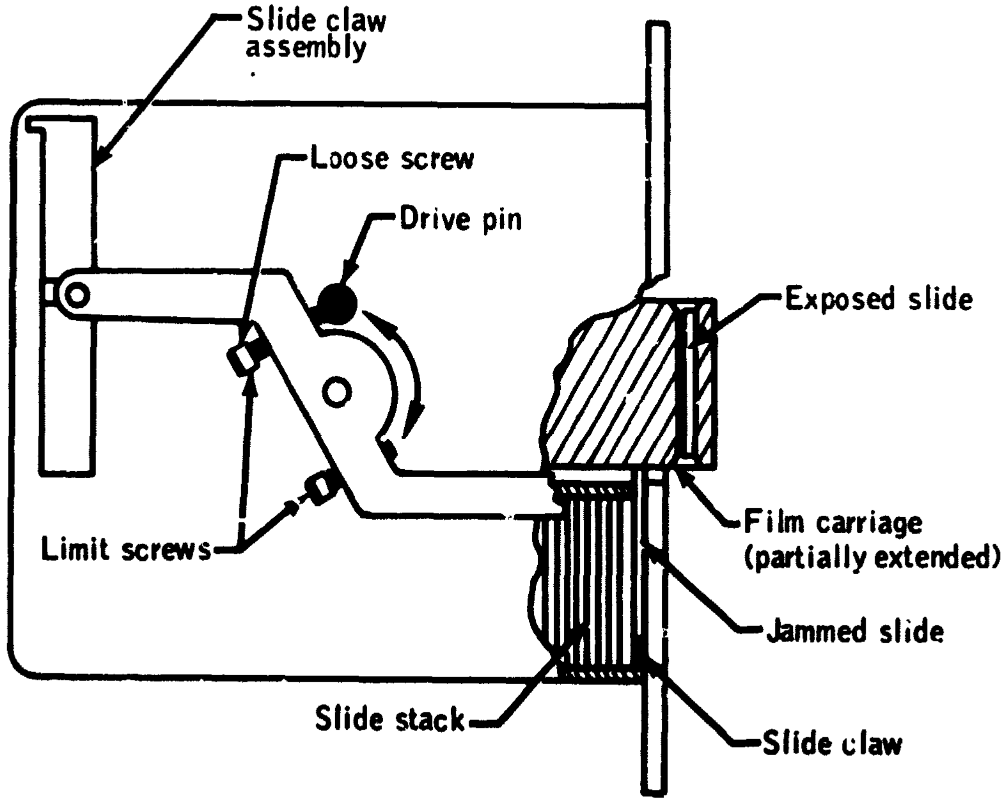


Figure 17-33.- Experiment S019 film canister.

Examination of the returned film canister showed that the slide pick-up sequence was initiated before the carriage retraction was completed. As a result, the slide that was being transferred from the supply stack for insertion into the carriage had jammed against the carriage slide guide.

The slide transfer sequence timing is controlled by two self-locking adjustable screws in the slide drive lever. These adjustable screws control the point at which the control crank drive pin engages the slide drive lever and starts the slide pickup and transfer motion and the return of the lever to the neutral position. The adjustable screw which engages the drive pin to start the sequence was loose and had moved about 3/4 of a turn from the proper setting. As a result, the slide moved toward the carriage before the carriage had fully retracted and aligned with the slides. When the screw was readjusted, the canister functioned properly. Torquing of the screw indicated that the nylon locking element no longer provided sufficient restraint.

The flight and backup film canisters for the third visit will have the two adjustable limit screws staked in the slide drive lever in addition to the existing nylon self-locking elements.

This anomaly is closed.

17.2.7 Experiment M171 (Metabolic Activity) Ergometer Was Intermittent

The experiment M171 ergometer load module began making excessive noise and eventually began free wheeling (no load) during the visit day 20 exercise period. After a 1-hour cooling period, the ergometer functioned properly and continued to operate normally for the remainder of the visit.

The ergometer (fig. 17-34) is a bicycle-like exerciser with pedals that drive an electrical generator (fig. 17-35). The generator output is loaded by a resistor. The torque and speed of the generator shaft are measured and multiplied together to produce a voltage proportional to the generator power output. The voltage, representing actual work performed, is compared to a desired work rate selected by the crewman. The voltage difference controls the electrical load applied to the generator. A force transducer is used to measure the generator torque. The force transducer (fig. 17-35) consists of a strain gage bridge mounted on a diaphragm. The center of the diaphragm is connected through a shaft to the generator stator. The stator is mounted on bearings and stator rotation is restrained by the force transducer.

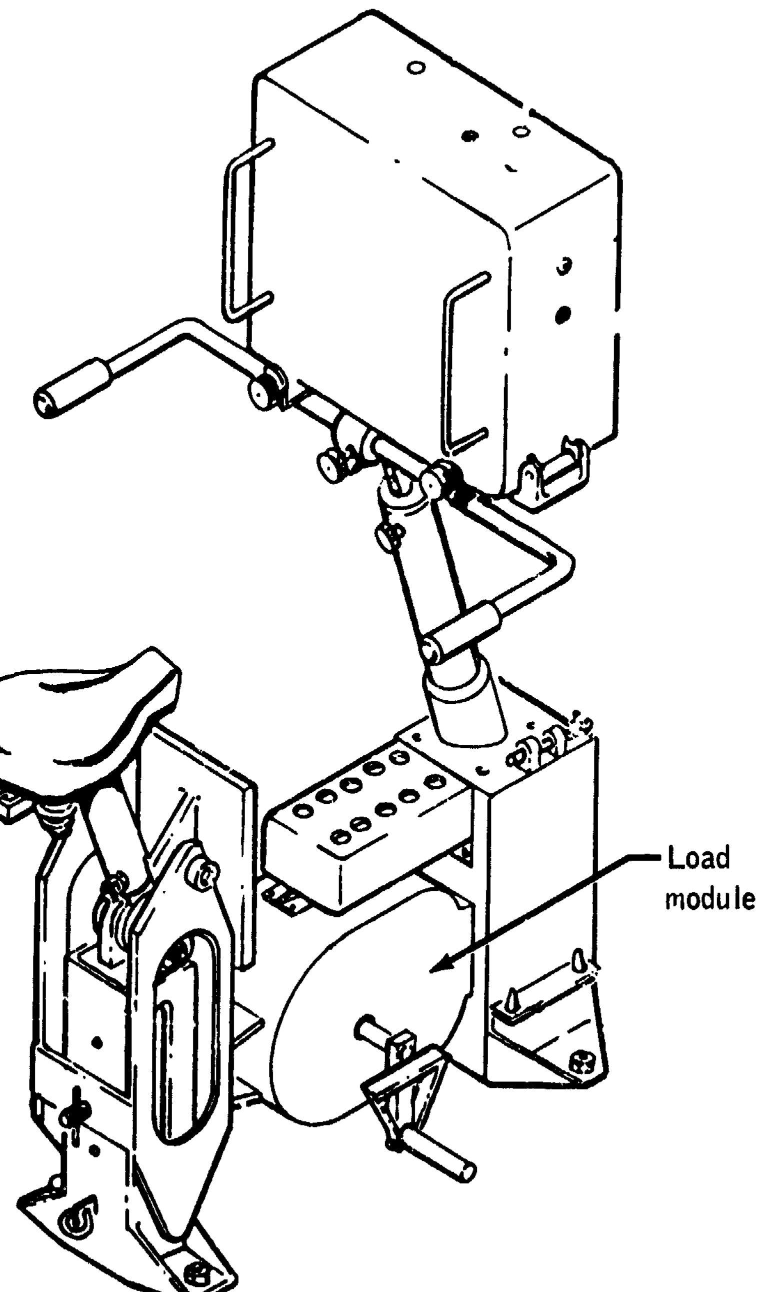


Figure 17-34.- Bicycle ergometer.

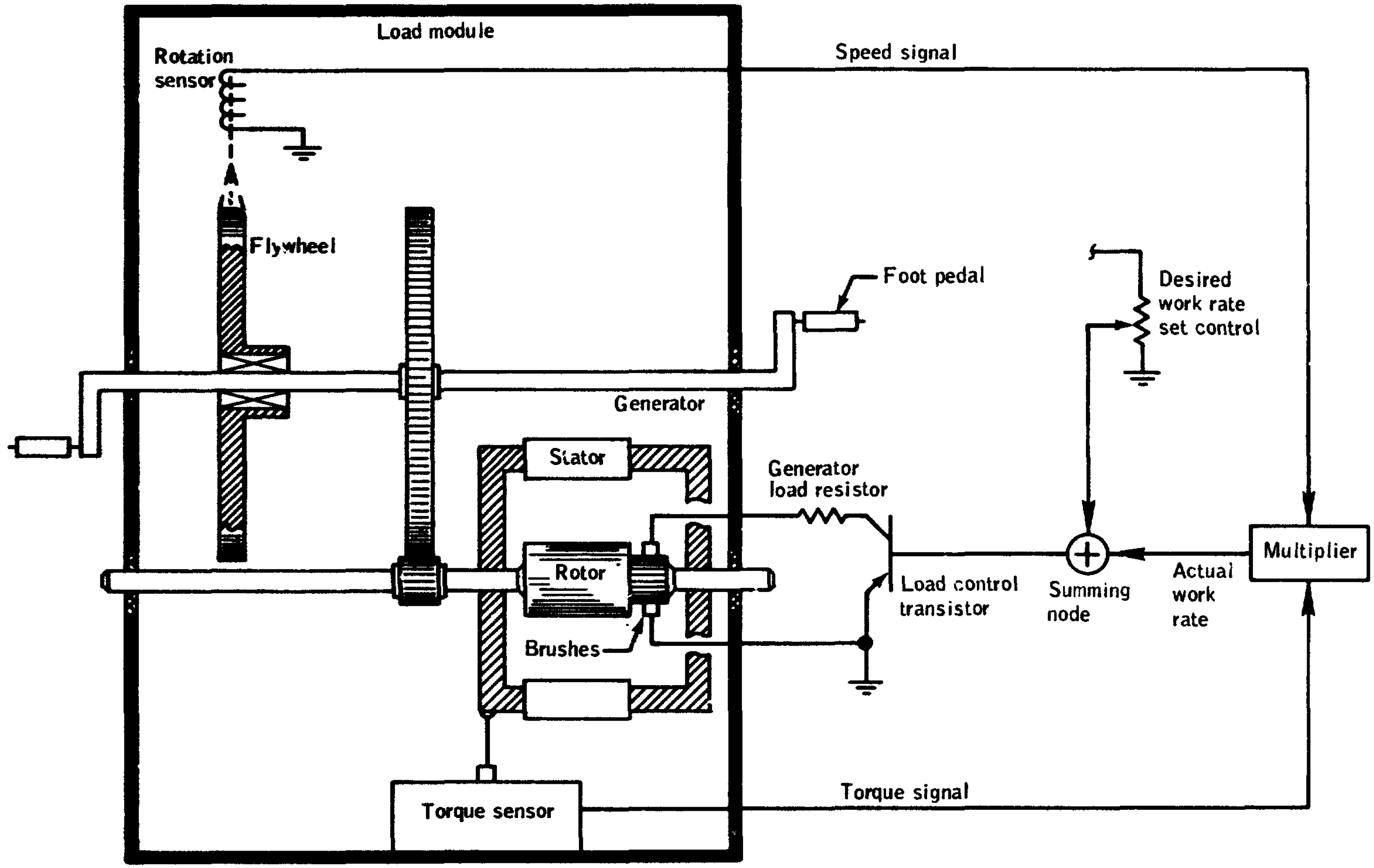


Figure 17-35.- Ergometer load control.

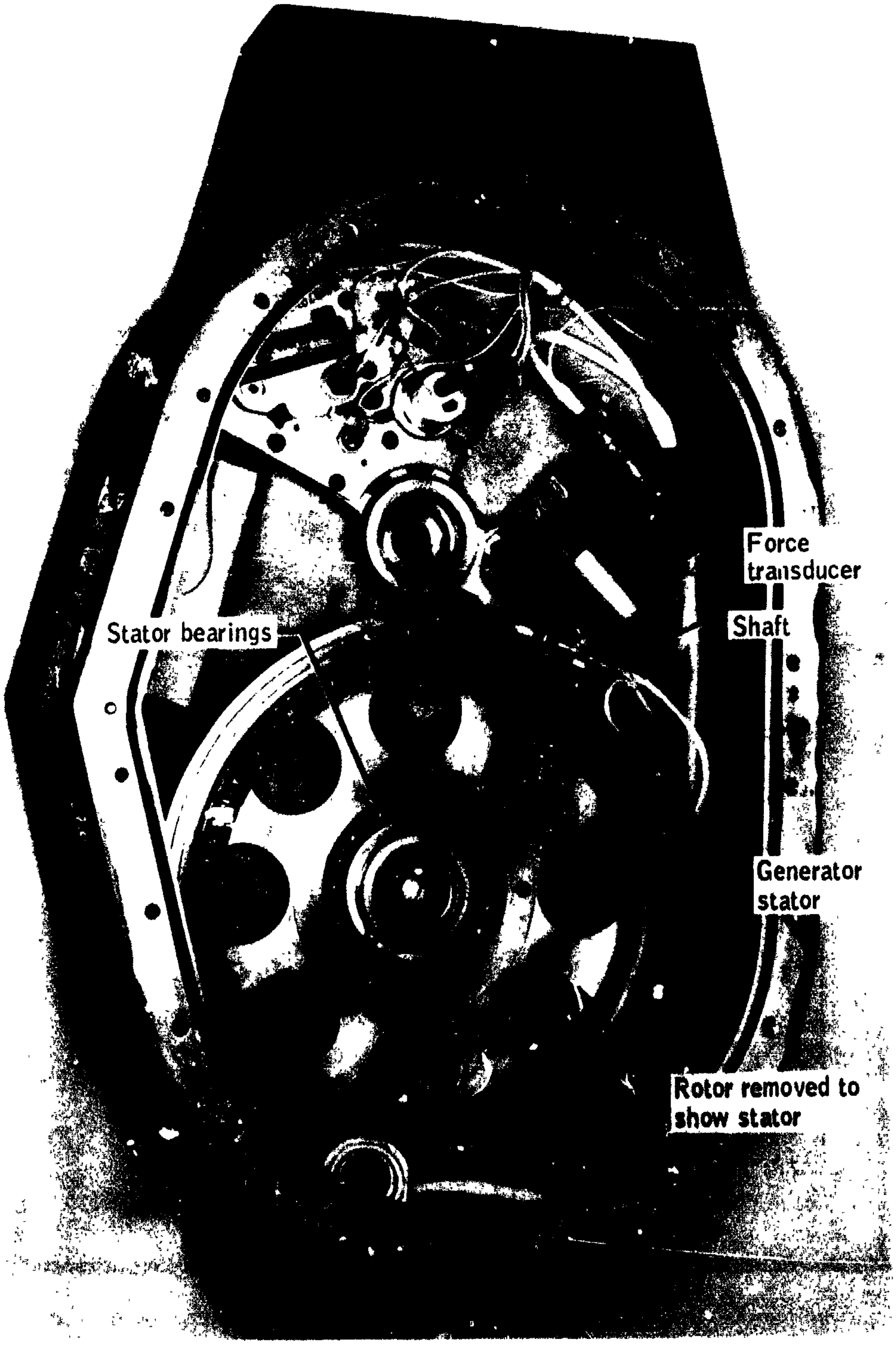


Figure 17-36.- Ergometer load module interior.

Two types of ergometer failures occurred during ground tests that resulted in excessive noise followed by free wheeling. The first was rotor thermal expansion, resulting from operating at excessive power levels, and causing the rotor to mechanically rub against the stator. When this occurred, sufficient force was coupled into the force transducer to break one of the strain gages. A failure of this type, however, is permanent, and could not have occurred to the flight unit as that unit operated normally after cooling down.

The second type of ground test failure was a cracked solder joint in the wire that connects the load resistor to the load control transistor. The resulting intermittent contact caused the load to be applied intermittently to the generator output and made the ergometer operation noisy.

An intermittent open circuit in the generator load loop or in the circuitry that controls the load control transistor could have caused the flight problem. Intermittents of this type can be exposed by elevated temperatures and can recover when returned to lower temperatures.

A spare ergometer load module is stowed aboard the Orbital Workshop. If the problem recurs, the load module can be replaced.

This anomaly is closed.

17.2.8 Experiment S190A (Multispectral Photographic Facility) Unexposed Film Frames

There were two extra unexposed frames found on the film from station 6 of the experiment S190A camera array. The first extra frame was found between frames 236 and 237, which were exposed on Earth Resources Experiment Package pass 29. The second extra frame was noted between frames 299 and 300, which were exposed on pass 41.

Figure 17-37 shows the logic and drivers that cause the magazine drive motor to advance film. The magnetic pickup consists of a ferromagnetic disc with a slotted air gap. The air gap produces a change in the magnetic reluctance of the sensor when the film transport is complete. This is converted to a negative going pulse by an integrated circuit which is in the pickup cartridge. This pulse is inverted and is one input to the film transport command gate. The other input to this gate originates in the forward motion compensator start gate. The forward motion compensation start gate is enabled at the proper time by the pulse counter and command storage flip-flop inputs so that the film advance occurs only when the capping shutter is in place. Both logic inputs to the film transport command gate must be absent to obtain an output. When the output is

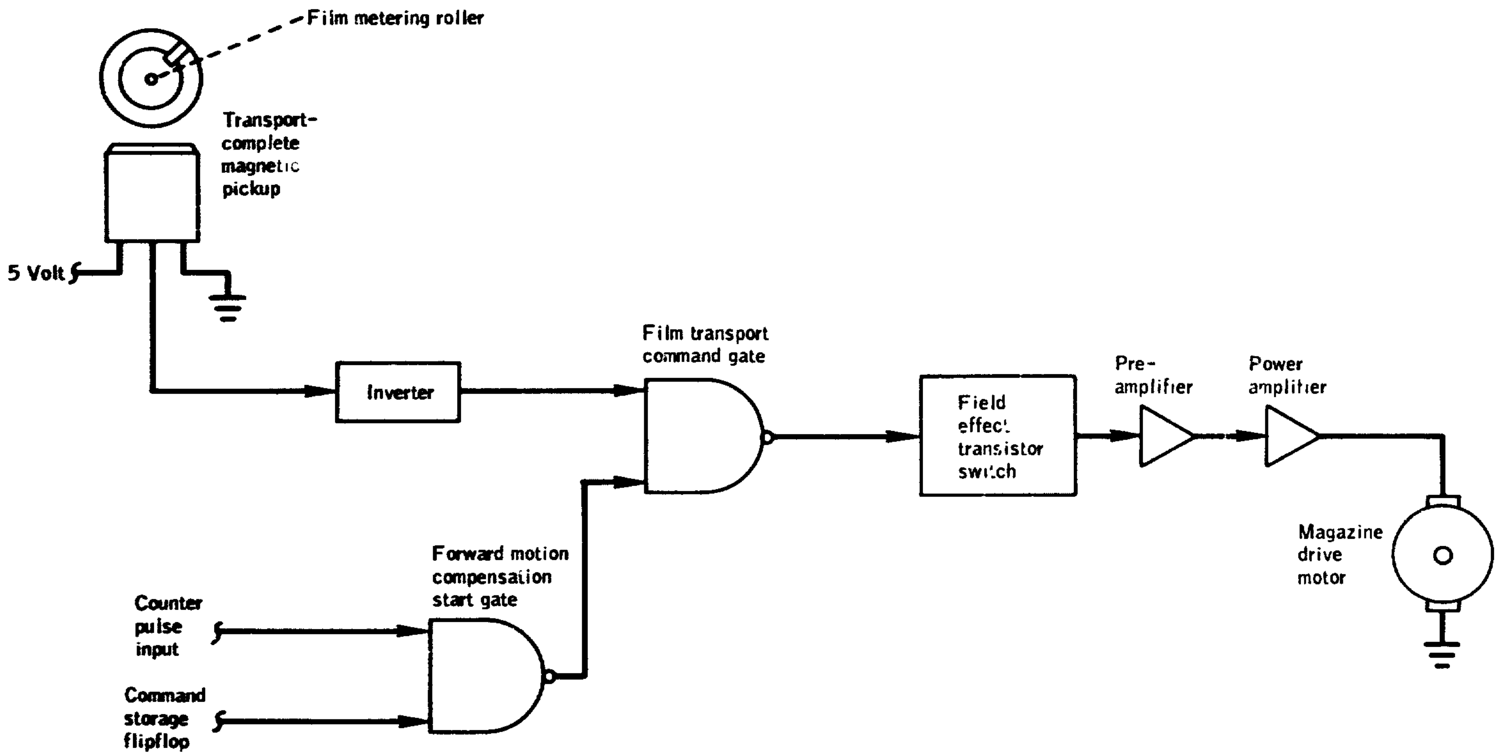


Figure 17-37.- S190A camera station 6 magazine drive logic.

present, the field effect transistor switch turns on the motor via the amplifiers. When the motor has pulled the film through one frame, the magnetic pickup generates a pulse which turns the motor off, completing the cycle.

If the transport-complete pulse is missing at the film transport command gate, the motor will pull through another frame without an exposure initiate command. A transient voltage spike of sufficient amplitude can initiate a trigger in the logic to the field effect transistor switch circuit which can also initiate film transport. Once started, this would continue until the air gap rotates a full revolution and stops the motor in the normal manner. An intermittent ground of the inverter input to the film transport command gate would also produce the same result.

The vendor's lot from which these magnetic pickups were taken has shown poor reliability. The dominate failure mode has been a loss of the pulse, which indicates the completed air gap revolution. However, these failures were not intermittent in nature.

Three replaceable assemblies within the experiment package may contain the source of the problem. These are the magazine drive assembly containing the magnetic pickup and motor; the logic board containing the pulse counter, command storage flip-flop, and logic gates; and the camera station control board containing the field effect transistor switch and amplifiers. All of these are replaceable in flight. A spare magazine drive assembly is on board and the crew is trained in replacement of this assembly. Spare logic and control circuit boards are also available for launch on the third visit.

The specific component responsible cannot be identified, but the magnetic pickup is the most probable suspect. If the intermittent condition becomes permanent, the magazine drive motor will continue to cycle until the film supply is exhausted.

Corrective action will be initiated only if the problem recurs and becomes worse. To determine if the conditions recur and become worse, the crew will compare the frame counter on station 6 with the frame counter at the other stations. The frame counter is mechanical and is independent of the logic-drive networks, so the indications will be the true number of frames advanced.

This anomaly is closed.

17.3 GOVERNMENT FURNISHED EQUIPMENT ANOMALIES

17.3.1 Mark I Exerciser Rope Failed

On visit day 23, the crew reported that the exerciser rope had broken. The 0.635 centimeter diameter polybenzimadazole rope was wound on the exerciser spool (fig. 17-38), which was of such a size that the rope was accomodated in one layer. A variable demand load on the spool was provided through the combination of a torsion spring, a gear train, a governor, and an adjustable clutch. The spool and rope were not covered by a housing.

The polybenzimadazole rope in the qualification test unit was subjected to 45 000 cycles with no significant fraying. However, in the test, the rope was pulled by a hydraulic cylinder, and each recoil was neat and uniform. On the other hand, when man uses the device, there is a tendency for the rope to cross-wind on itself on the spool. Repeated cycles with the rope abrading against itself because of cross winding, causes a weakening of the rope. The polybenzimadazole rope is particularly susceptible to this type of failure.

Replacement rope is on board. Procedures to replace the broken rope were transmitted to the crew and replacement was accomplished.

This anomaly is closed.

17.3.2 Apparent Leakage of Liquid Cooling Garment

The Commander reported finding a few drops of liquid on his liquid cooling garment after the second extravehicular activity.

The liquid cooling garment (fig. 17-39) cools the body by circulating water at a constant inlet temperature through a network of tubing. The garment is worn next to the skin and is the primary means by which a crewman is cooled.

The garment consists of an outer layer of nylon material, water connectors, inlet and outlet manifolds; a network of polyvinylchloride distribution tubing; and an inner nylon chiffon comfort liner.

Upon removal of the liquid cooling garment after the second extravehicular activity, the crewman reported that liquid leakage was occurring and had dampened the garment in the area between the multiple water connector and the junction at the first manifold (fig. 17-39). The Commander also stated that this leakage had occurred after the suited run with experiment M509 and that efforts to detect the location of the leak by squeezing the liquid cooling garment tubes were unsuccessful.

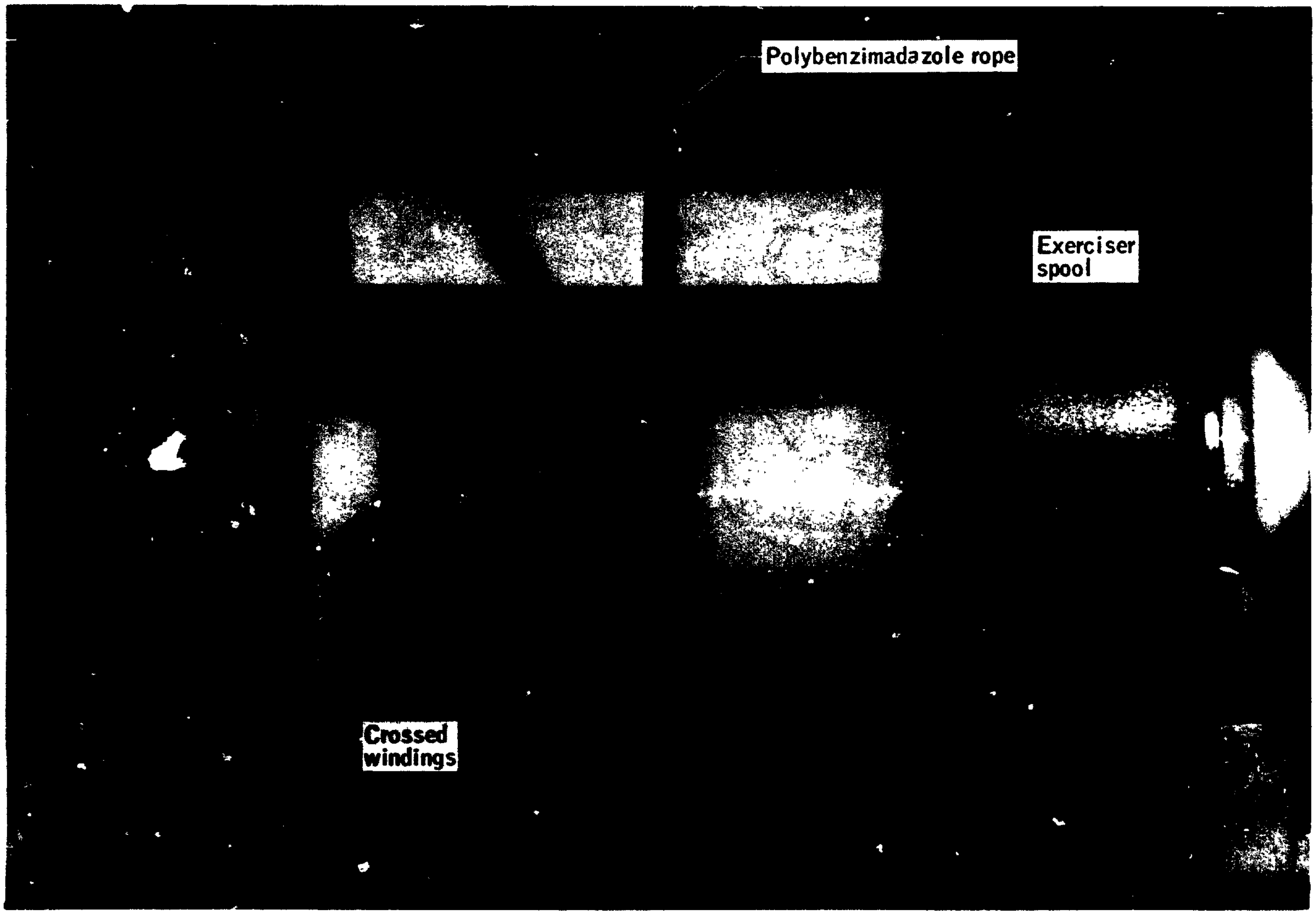


Figure 17-38.- Mark I exerciser.

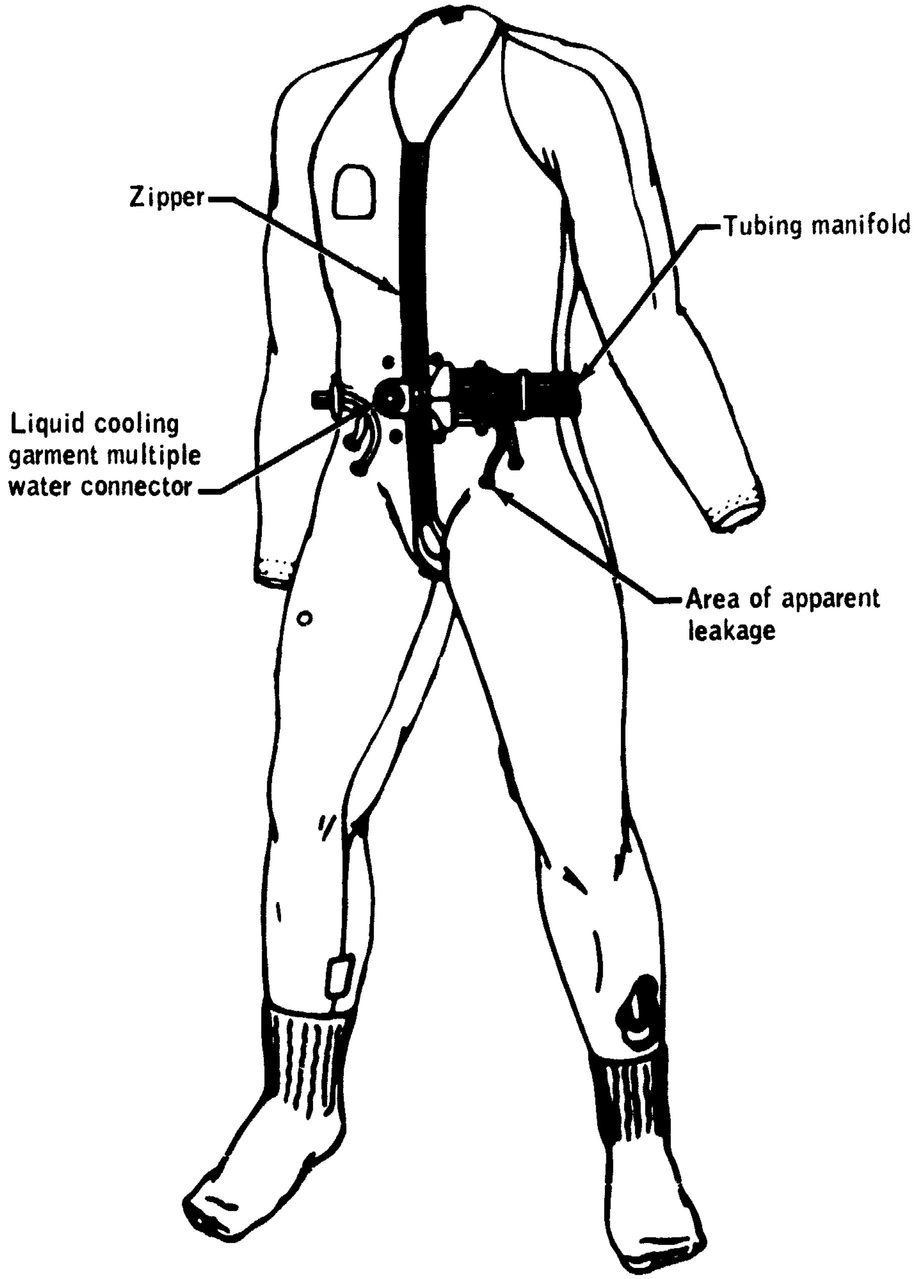


Figure 17-39.- Liquid cooling garment.

The garment was returned and leak tests were performed; however, no leak was found.

Two potential causes of the apparent leak are: (1) Condensation may have collected on the tube and wetted the garment. If condensation was the cause of the accumulated water, other areas of the garment should also have been wet because the tubing in other areas of the garment is as cold as the area where the liquid was found. (2) The urine collection and transfer assembly may have leaked urine into this area. However, urine should have stained the garment and no stain was found during the postflight inspection.

Postflight testing produced no leakage in this garment, and the source of the liquid is unknown.

This anomaly is closed.

17.3.3 Television Camera Failed

The picture information portion of the composite video signal was lost on one of the television cameras during the extravehicular activity operation on visit day 28.

The Skylab television camera circuitry is shown in figure 17-40. The image tube is an electron bombardment silicon type. The photocathode element is at the face of the tube and is maintained at minus 10 000 volts. Photoelectrons are ejected from the photocathode element in direct proportion to the radiation photons impinging on it. These photoelectrons are focused upon the target, which is a thin mosaic of diodes at about 155 diodes per square centimeter. These diodes are charged by the photoelectrons and retain the charge until they are scanned and discharged by a scanning beam, which impinges on the reverse side of the target, from the electron gun consisting of a cathode and four grids. Thus, an illumination intensity signal is generated at the target and coupled to the video module, and this signal is time related to the horizontal and vertical position of the scanning beam.

The illuminance signal is mixed with the horizontal and vertical synchronization pulses, temperature, and the vertical interval test signal to form the composite video signal which is amplified in the video module and fed to the command and service module S-band system for downlinking to the ground.

The illuminance component of the composite video signal was lost. In place of the video signal was a pattern of noise that gave the appearance of horizontal streaks on the television display. The synchronizing

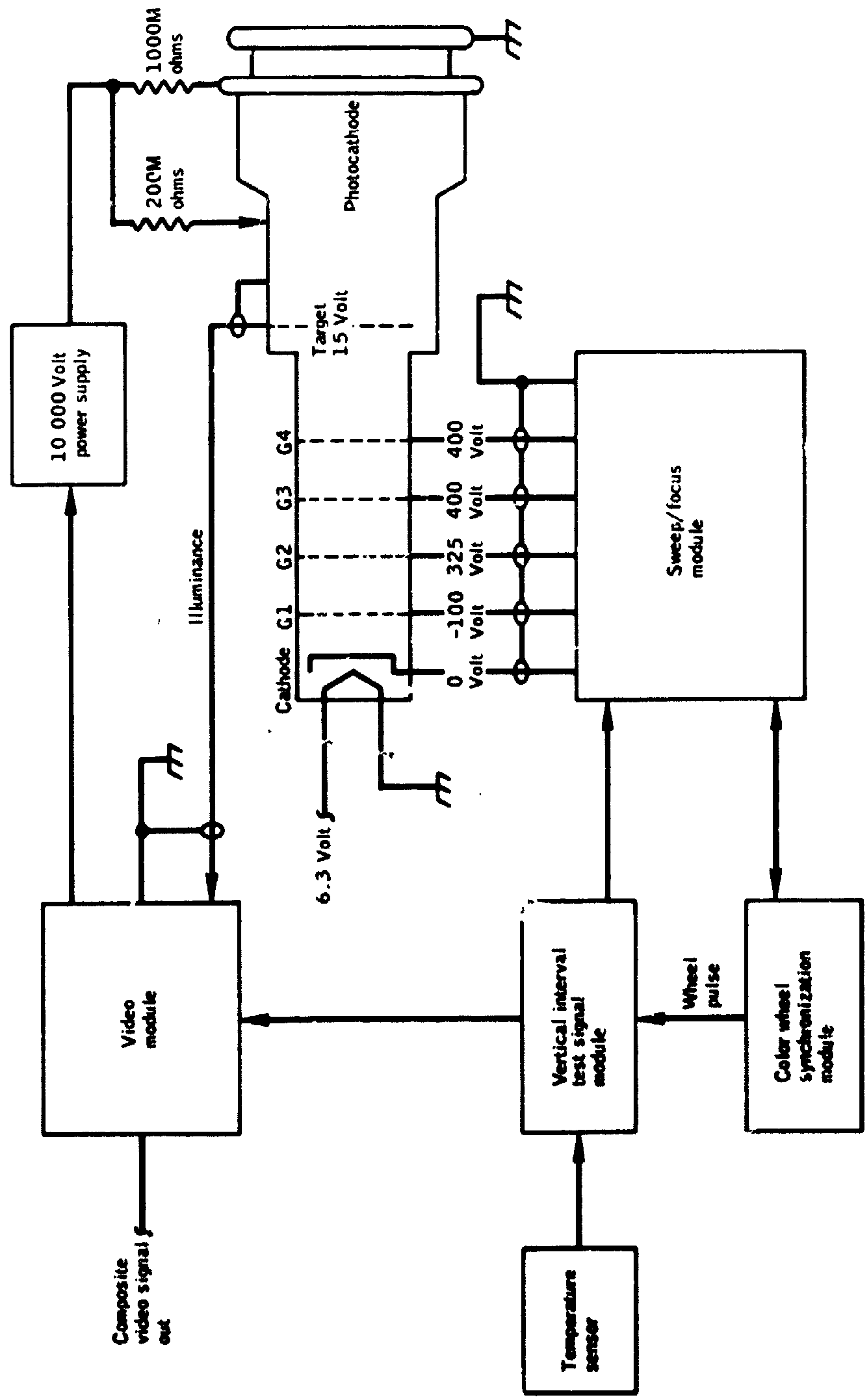


Figure 17-40.- Television camera network block diagram.

signals, vertical interval test signal, and temperature information were still being transmitted to the ground. The failures which result in loss of illuminance, but permit the remainder of the composite video to be present, are grounding or shorting of the image tube electrodes (fig. 17-40).

Figure 17-41 is an enlarged drawing of the objective portion of the image tube. During high temperature vacuum testing to flight qualify the television camera, an image tube failed. The failure was caused by room temperature vulcanizing material expanding and filling the small ullage volume of the image tube, thus exerting a tension force at the glass-to-Kovar junction, and fracturing the glass. The test temperature was 343° K, but the temperature at which the fracture occurred was not known.

The failed flight camera was not modified to incorporate the design change which reduced the room temperature vulcanizing material fill level. An upper temperature limit of 260° K was established for mission operations to prevent image tube breakage. A second high temperature vacuum test was successfully performed at this lower temperature. Data showed the flight camera reached 345° K during the last pass with good illuminance information still being produced.

The crew reported a burnt rag odor coming from the camera the day following the extravehicular activity. This could have been either a resistor or insulation overheating and decomposing as a result of a short to ground of one or more of the image tube electrodes or the 10 000 volt power supply output. Also, the horizontal streaks observed in the television display when the camera failed can be caused by high voltage arcing.

The probable cause of the failure was a temperature-induced image tube fracture followed by high voltage arcing or shorting of the image tube electrode.

A replacement camera will be supplied for the third visit.

A procedure has been provided to exercise thermal control of the image tube.

This anomaly is closed.

17.3.4 Video Conductor in Television Power Cable Failed

Experiment S192 (Multispectral Scanner) data downlinked through the Earth Resources Experiment Package downlink diagnostic unit was intermittent on visit day 43. On visit days 44, 45, and 46, satisfactory data and video transmissions were downlinked. When the ground dumped a video tape recording on visit day 47, the Apollo Telescope Mount video signal was readable, but there was no signal from the portable television camera.

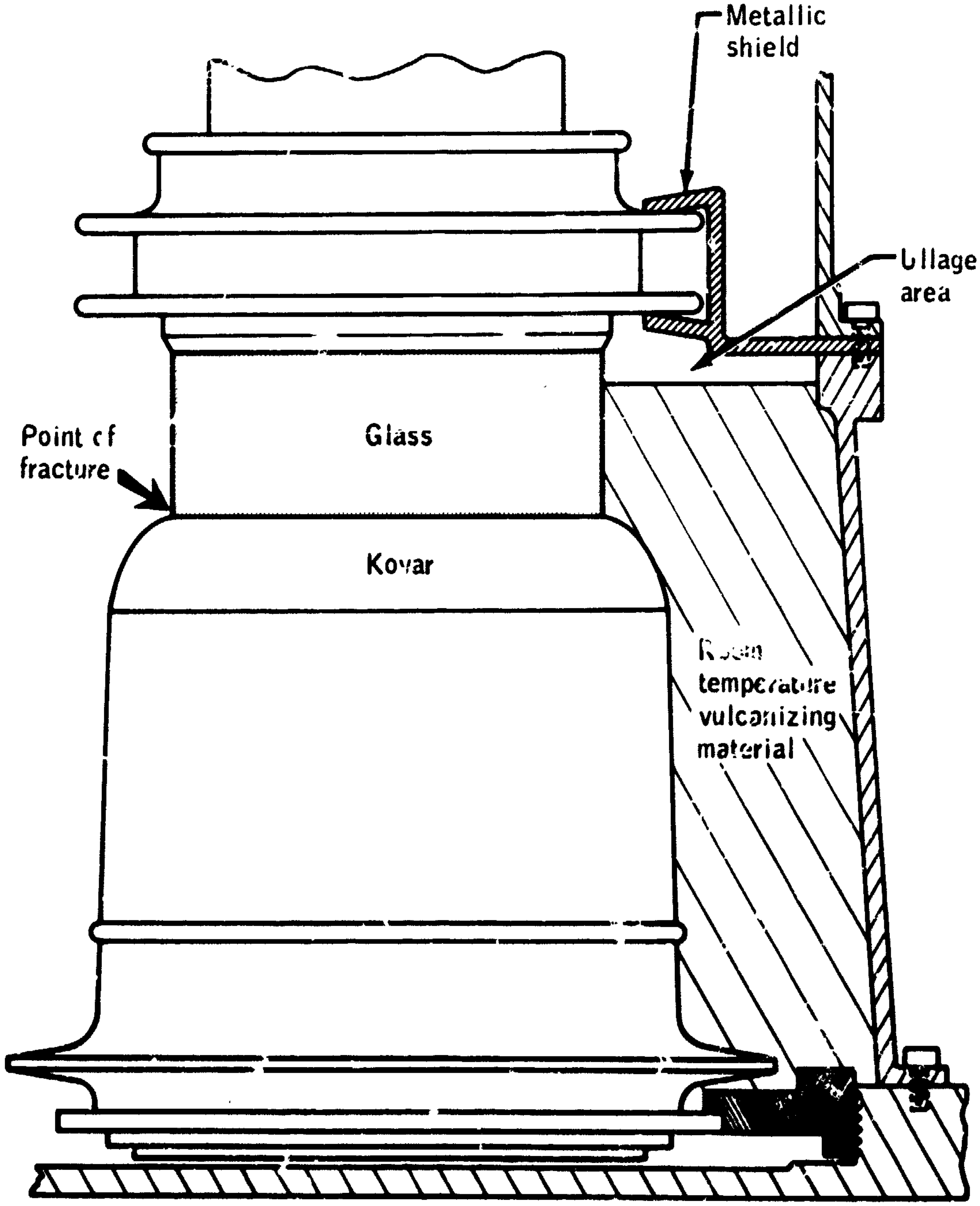


Figure 17-41.- Objective portion of television image tube.

The Orbital Workshop video system has both a live transmission and recorded transmission capability of either Apollo Telescope Mount video sequences or portable television camera sequences. The system has also the capability to record and transmit real-time Earth Resources Experiment Package data to the ground as shown in figure 17-42.

The Earth Resources Experiment Package downlink diagnostic unit has the capability to transmit any one of ten Earth Resources Experiment Package data channels in real time through a selector switch and cable interconnections to the television input station in the Multiple Docking Adapter.

The single channel of data from the downlink diagnostic unit is transmitted by a television power cable (fig. 17-43) to television input station 133. The television power cable may be disconnected from the downlink diagnostic unit and connected to the portable television camera. The downlink diagnostic unit is only used with the Multiple Docking Adapter television input station, whereas the portable television camera may be connected through the television power cable to any television input station.

The video signal from the Multiple Docking Adapter station is fed to the video selector switch. This switch is positioned to carry either a television input station signal or a signal from the Apollo Telescope Mount television monitor 1 or 2.

The signal passes through a switch and is fed to a video tape recorder where it may be recorded for later transmission or, in the bypass mode, is fed to the command and service module for real-time transmission to the ground.

Experiment S192 data were downlinked on visit day 43 and the ground station reported that the data were noisy. Examination of the data tapes showed that the data bit stream was intermittent. The frequency modulation downlink signal strength was normal at the time the problem occurred.

Further data were downlinked on visit days 44, 45, and 46, and no bit stream dropouts were noted. During these three days, other television transmissions were also satisfactorily downlinked.

On visit day 47, an Apollo Telescope Mount video tape recording was made, followed by a portable television video tape recording. The ground station experienced trouble dumping the video tape recorder. A review of the ground tape showed the Apollo Telescope Monitor video signal was readable, but from the point where the recording of the portable television sequence of a medical experiment should have started, the signal could not be demodulated.

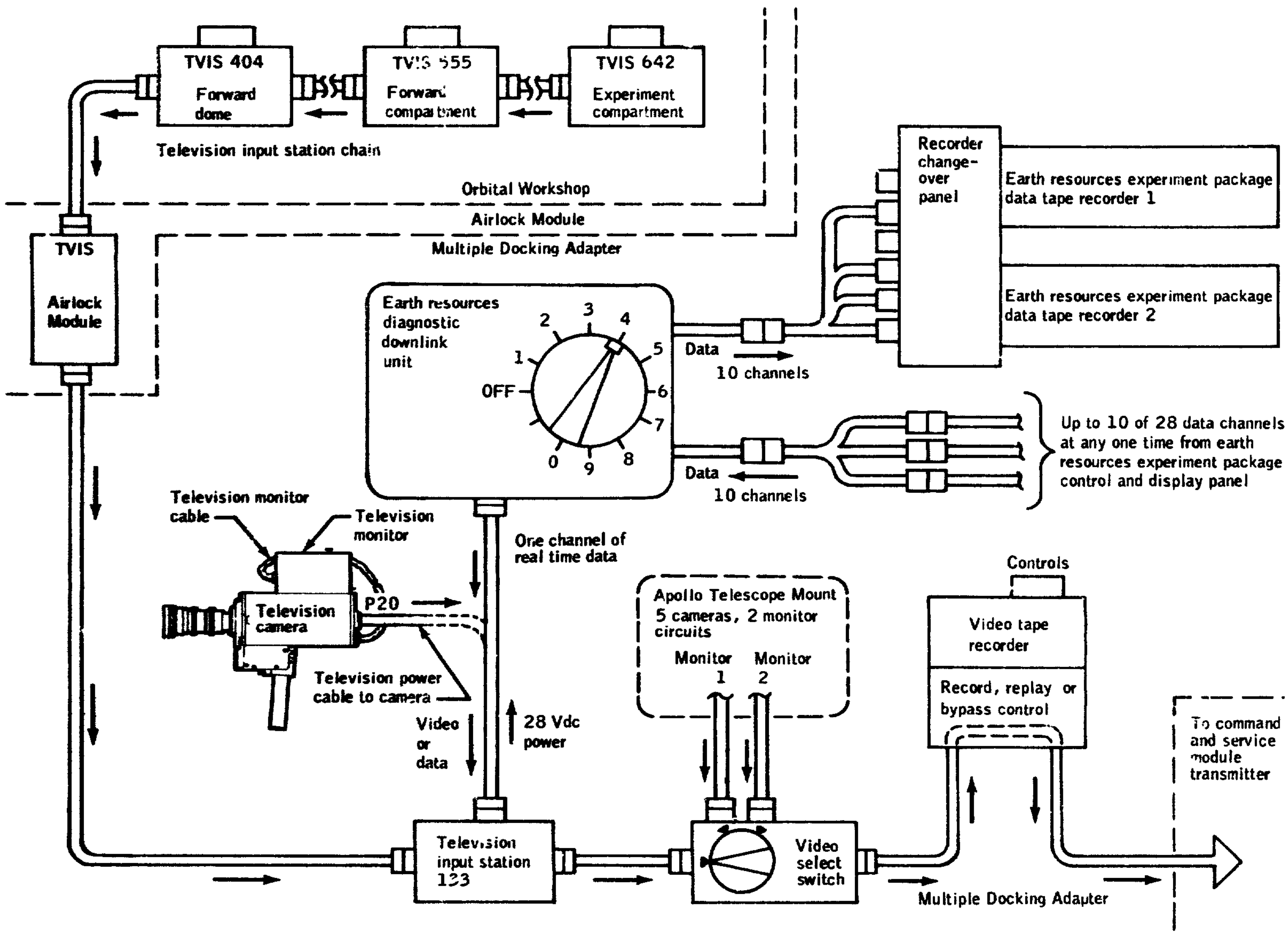


Figure 17-42.- Simplified video system block diagram.

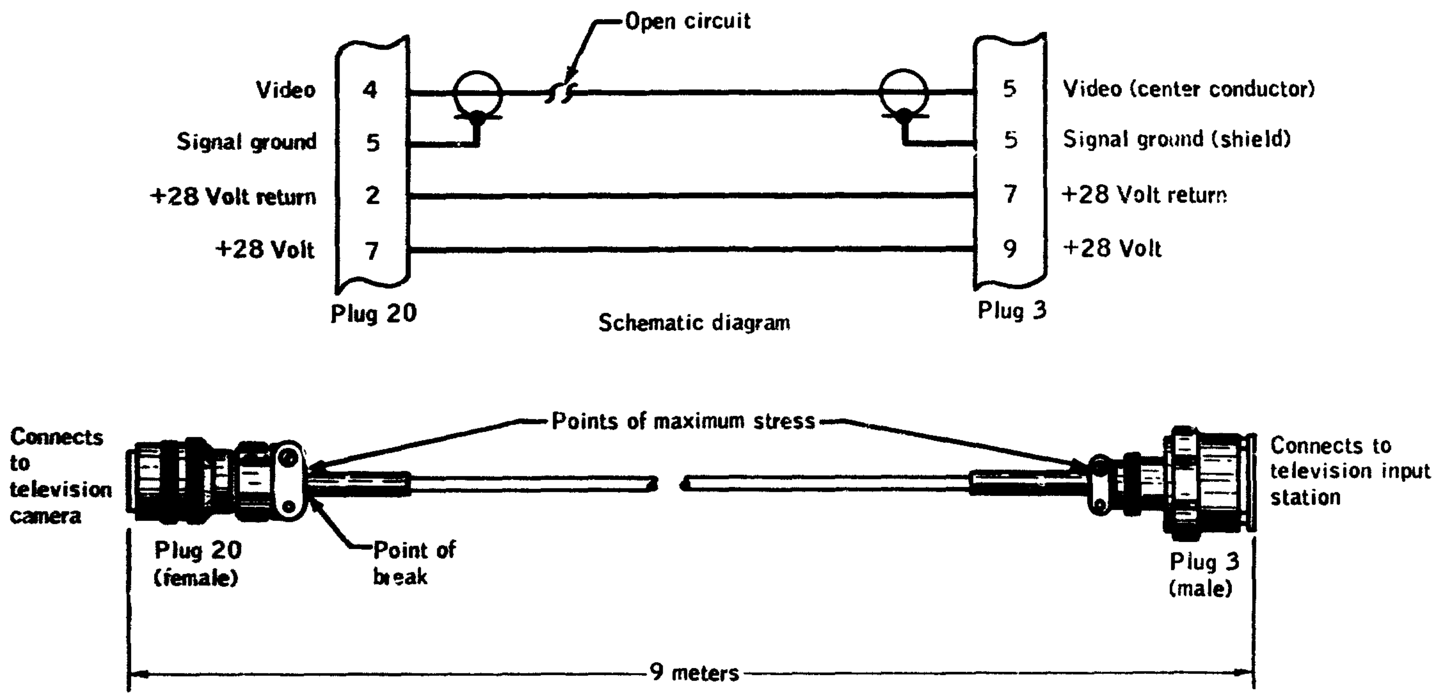


Figure 17-43.- Television power cable.

The crew checked the television power cable, and found that the coaxial center conductor that carries the video signal was open. Ground testing verified that the break was located as shown in figure 17-43.

The Apollo Telescope Mount transmissions are not carried by the television power cable and therefore were not interrupted. The open coaxial conductor probably caused the intermittent bit stream in the downlink diagnostic unit data, and four days later, the total loss of the portable television camera video signal.

A replacement television power cable will be carried on the third visit.

This anomaly is closed.

17.3.5 Television Monitor Picture Lost

During a video tape recording sequence on visit day 48, the television monitor did not exhibit a picture of the experiment operations in progress. The screen showed only a gray raster consisting of uniform scan lines. The crew switched monitors and the new monitor worked properly.

A half hour later, the crew reported that the replacement monitor had been operating intermittently a few minutes earlier, and also during the tape recording and for an undisclosed period earlier in the mission. The picture occasionally collapsed to a horizontal line and then reappeared, which is symptomatic of interrupted power to or inside the monitor.

The camera has two isolated video outputs, one of which is transmitted through the television power cable to the input station for transmission to the ground, and the other is transmitted to the onboard television monitor through a television monitor cable (fig. 17-44). The television monitor cable also provides electrical power from the camera to the monitor.

On visit day 51, the crew checked out the television monitor cables. The monitor cable in use produced an intermittent monitor picture when it was flexed near the plug where the cable connects to the camera body. Testing this cable with the replaced monitor produced the same collapsing picture condition, but both monitors operated satisfactorily with the spare monitor cable.

The condition that the original monitor exhibited, a gray raster, was not reproduced.

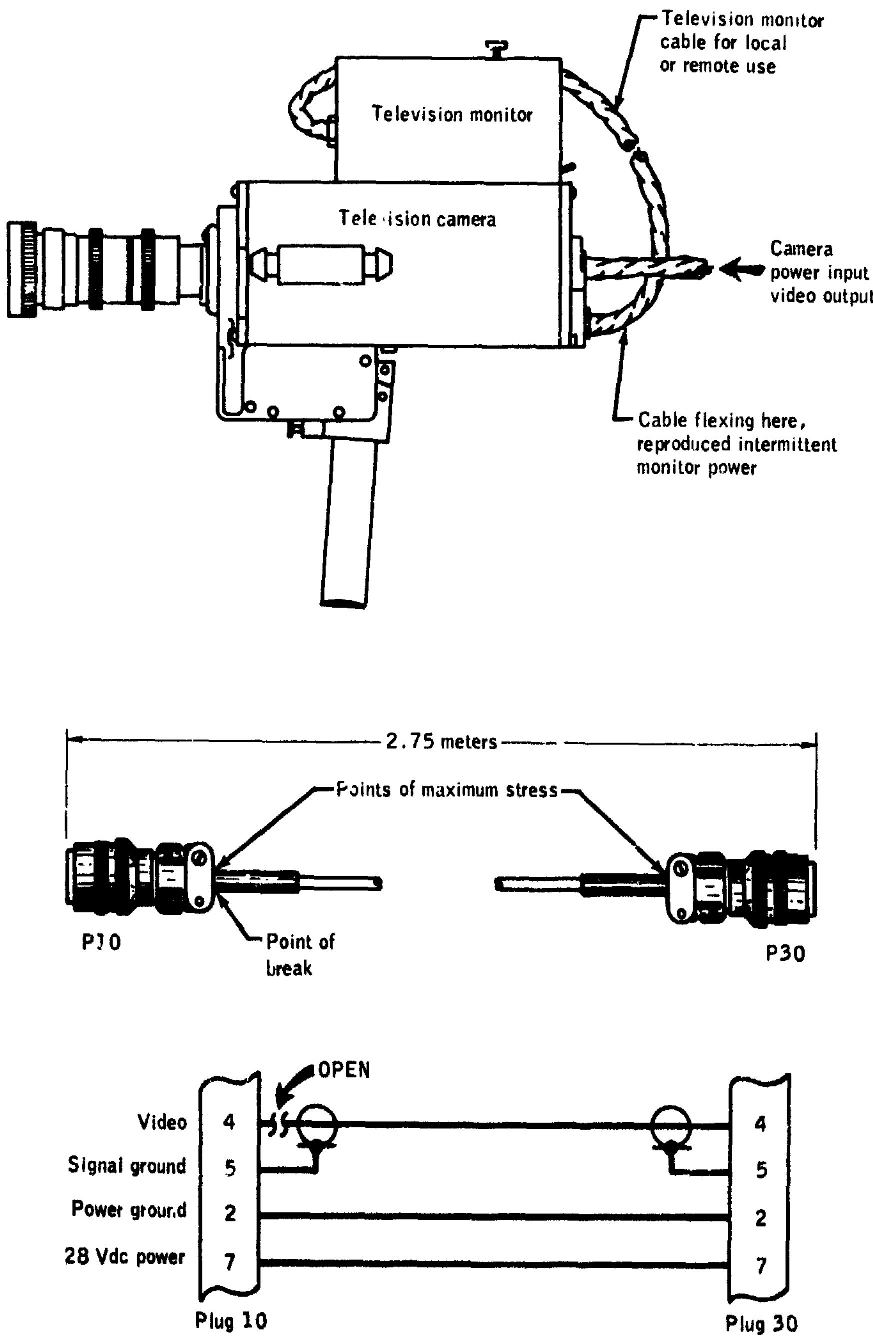


Figure 17-44.- Television monitor cable.

An open in the coaxial cable center conductor was found in the returned monitor cable.

The gray raster condition was caused by the open in the monitor cable. The collapsing picture problem may have been caused by an internal problem which may still exist, but was not evident after the exchange of cables.

A replacement television monitor cable will be carried on the third visit along with an additional monitor.

This anomaly is closed.

17.3.6 16-mm Camera Transporter Indicator Lights Erratic

On viist day 31, both the thread and end film indicator lights were erratic on a 122-meter film transporter. The camera used with the transporter was replaced and the transporter indicator lights resumed normal operation.

The camera supplies plus 28 Vdc power to the film transporter through an electrical interface. The interface consists of two bellows contacts on the camera and mating pin contacts on the transporter. When a transporter is mounted on a camera, the transporter pins depress the camera contacts (fig. 17-45), providing electrical connections.

The camera used with the transporter was carried aboard the command module for the second visit. Three 43-meter film magazines were used with this camera during comand and service module operations. The 122-meter film magazine transporters were used with this camera during Orbital Workshop operations. The camera was mated to these reloadable transporters 33 times. This totaled 36 matings of the camera's electrical contacts. After the 37th mating, the lights on the film transporter were erratic.

During ground testing, camera failures occurred in which one or more bellows cracked and lost return force. This type of failure would cause the failure seen in flight.

Six cameras may be used at one time in the Orbital Assembly. There are nine operating cameras on board which is adequate for the third visit.

This anomaly is closed.

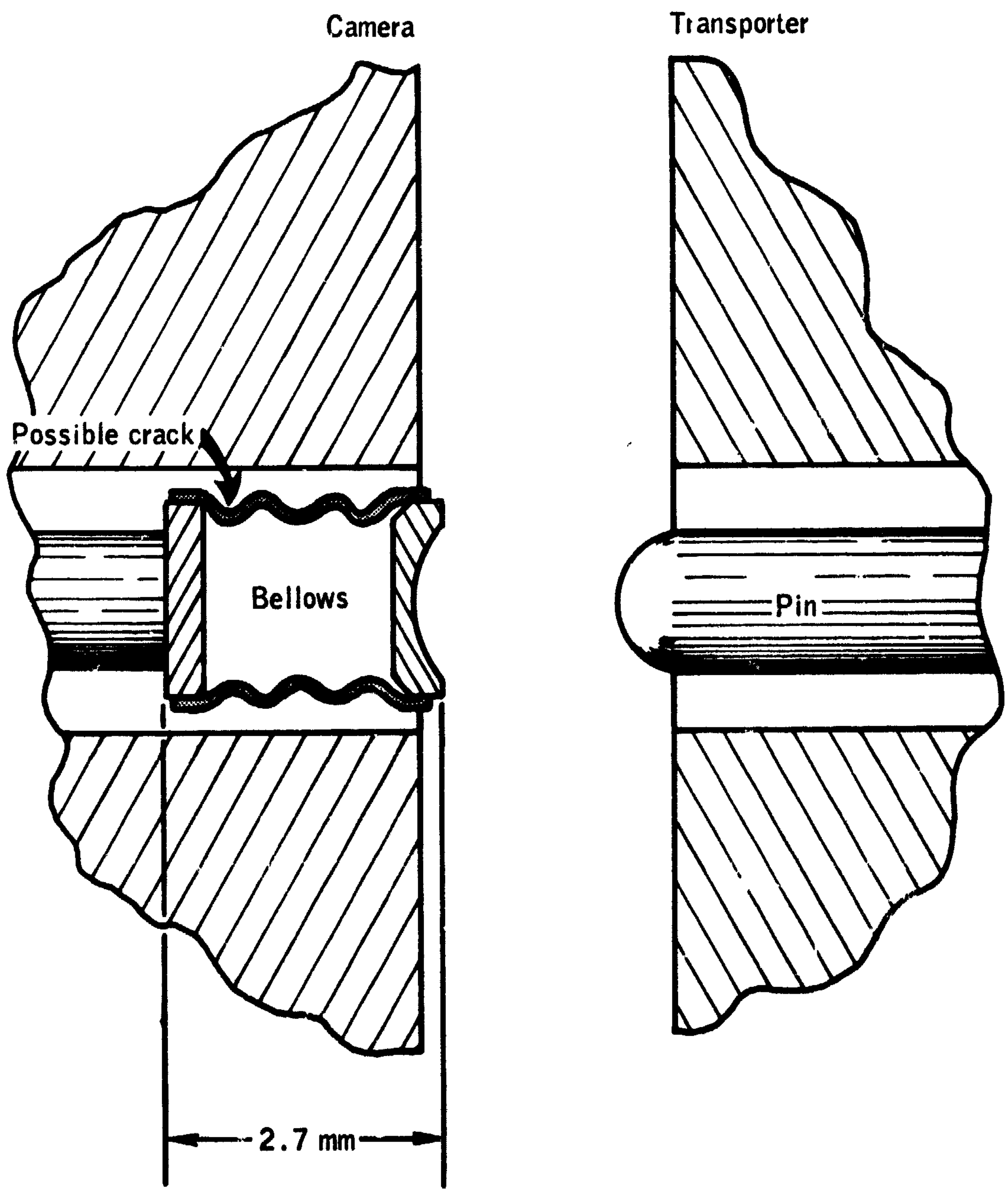


Figure 17-45.- Camera and transporter electrical interface contacts.

17.3.7 Hand-Held Microphone Output Noisy

The hand-held microphone assembly consists of the microphone, the microphone amplifier, and a 4.5-meter-long twisted shielded pair interconnecting cable between the microphone and the amplifier. The hand-held microphone output was excessively noisy during the playback of the web formation experiment data on the video tape recorder.

The amplifier was originally designed to operate with the lightweight headset which uses two microphones connected in series opposition to cancel in-phase acoustic noise inputs as shown in figure 17-46. In that case, each microphone output was connected across one of two series resistors, which were then connected between the inverting and noninverting amplifier inputs.

In the hand-held microphone application, the microphone output was connected across one of the two series resistors as shown in figure 17-47. The microphone cable shield was grounded at a point different from the vehicle ground point. A ground loop voltage between the two ground points was then coupled from the cable shield to the cable conductors through the shield to conductor capacitance and a noise current resulted as shown in figure 17-47. Since the noise current flowed through resistors R1 and R2, a voltage was developed across resistor R1 in series with the microphone output and was connected between the amplifier inverting and noninverting inputs (noncommon mode). Tests showed that this noise voltage input resulted in the high amplifier output noise level.

Two modified hand-held microphones will be supplied on the third visit. The microphone output will be connected across both amplifier input resistors, that is, between the amplifier inverting and noninverting inputs as shown in figure 17-48. The resulting noise currents will still develop a noise voltage across resistor R2, but this voltage will be common mode, that is, applied equally and in-phase to both amplifier inputs. The amplifier is designed to reject common mode inputs; consequently, the noise voltage will not appear in the amplifier output.

This anomaly is closed.

17.3.8 Erratic Operation of 35-mm Camera Incrementing Frame Counter

The 35-mm camera incrementing frame counter occasionally missed frame counts. The frame counter resets each time the camera back is opened. When the film is loaded, and the camera back is closed, the film is manually advanced to the point where the number 1 shows on the counter. Each time the film is advanced one frame, the counter increments by one count and, in this manner, the counter indicates the number of frames used.

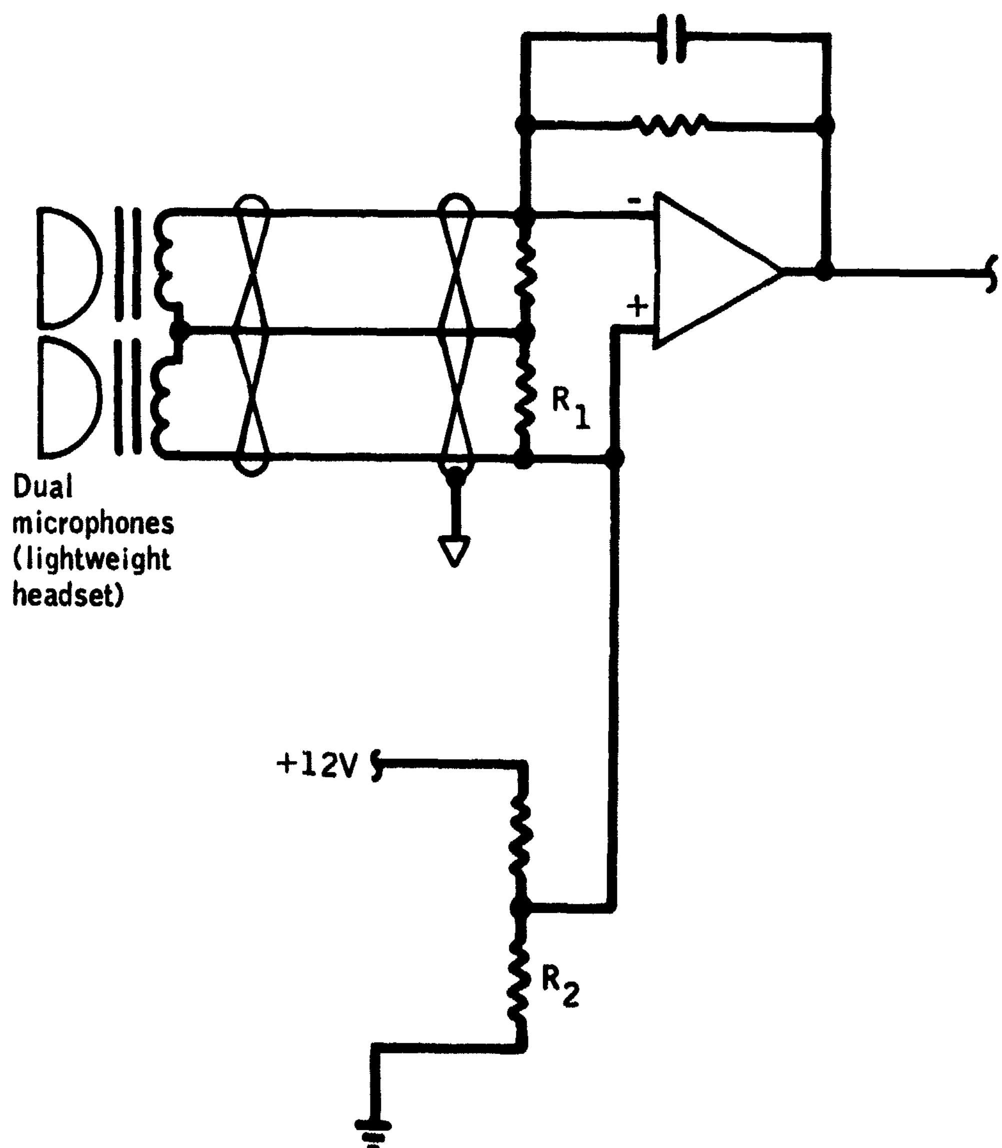


Figure 17-46.- Light weight headset amplifier input circuit.

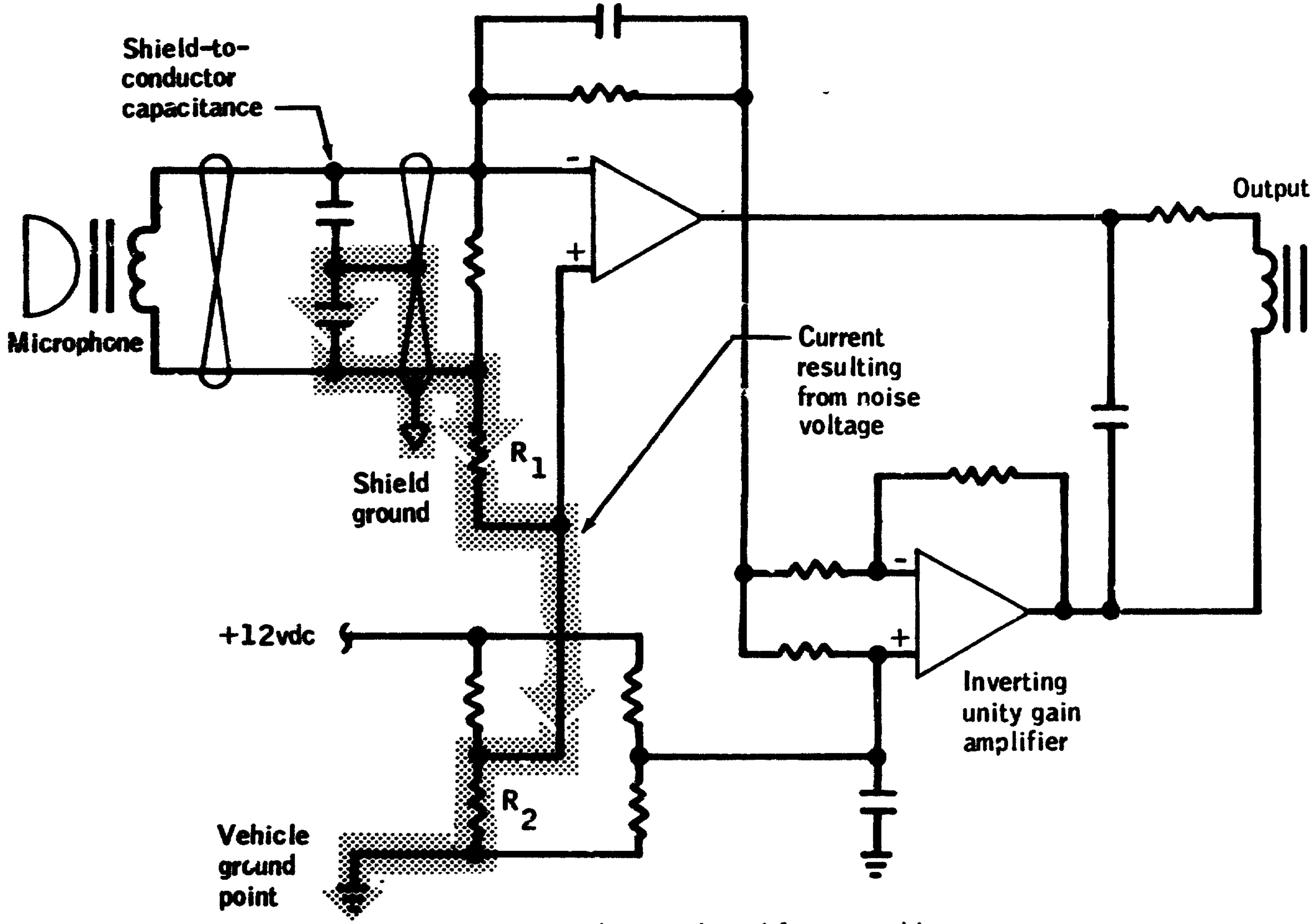


Figure 17-47.- Microphone and amplifier assembly.

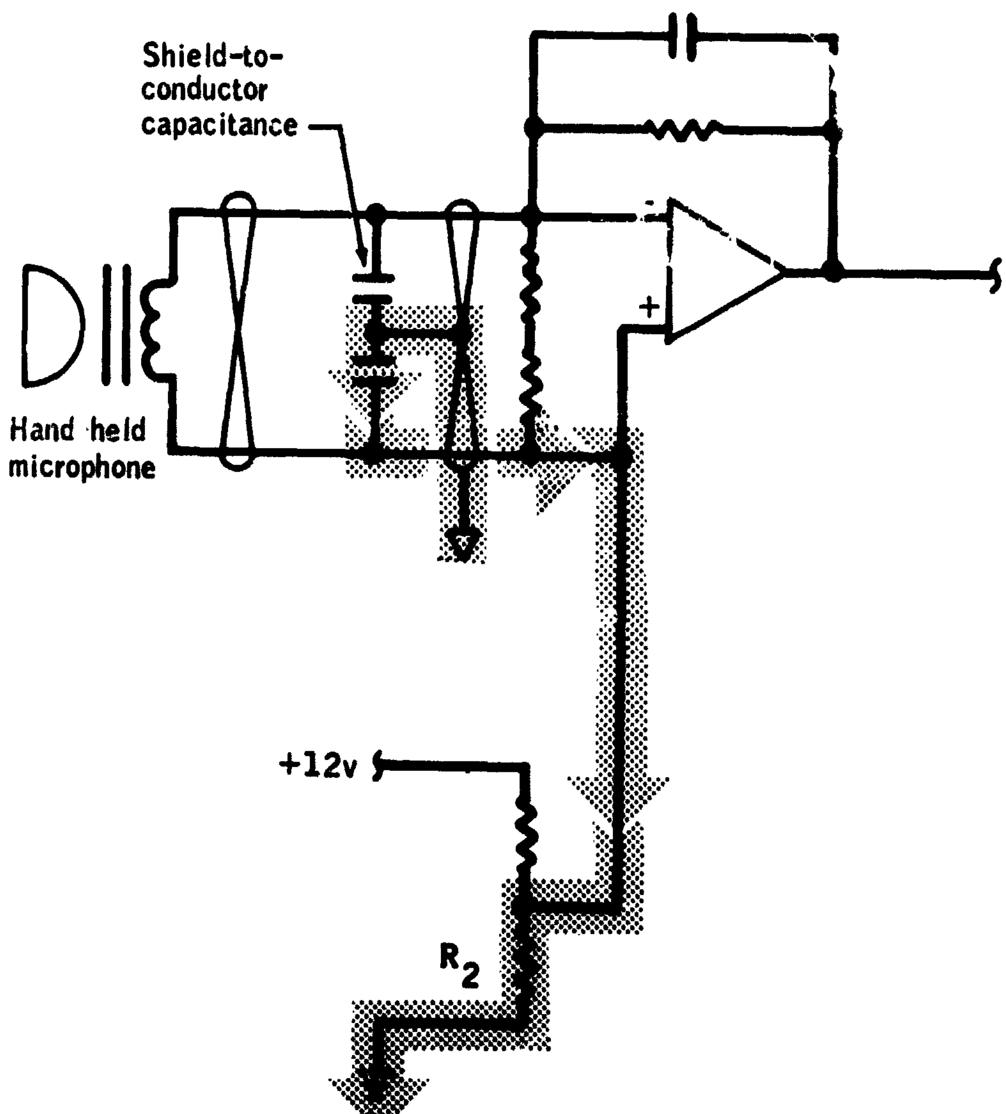


Figure 17-48.- Modified hand-held microphone input circuit for third visit.

When the camera back is closed after loading the film, a tab on the camera back cover depresses the counter engage lever on the camera. This depression pushes a linkage assembly which engages the teeth on the counter mechanism so that the counter is incremented one count for each frame advance.

The most likely cause of the lost counts was an insufficient depression of the counter engage lever. As a result, the linkage did not fully engage, which allowed random skipping of the frame counts.

The camera also has a decrementing counter which is manually set to the maximum number of frames in the loaded film roll. The counter is directly driven by film spool movement.

A procedural change was implemented during the first visit to use only the decrementing counter which provides an accurate indication of film usage.

The camera was not returned and no crew repair will be attempted as this problem has no effect on the mission.

This anomaly is closed.

17.4 FIRST VISIT ANOMALIES CLOSED SINCE REPORT PUBLICATION

17.4.1 Improper Optics Trunnion Angle Counter Operation

On three separate occasions during the first manned visit, the optics trunnion angle counter in the computer changed at rates as high as 0.698 radian per second while the optics system was in the zero optics mode. The optics system uses synchro-resolvers to measure the positions of the optics shaft and trunnion axes.

The trunnion resolver output is supplied to the coupling data unit (fig. 17-49), which converts changes in the resolver analog signal to a series of digital pulses. These pulses are then used to increment or decrement the trunnion register in the command module computer.

Resolver output and read counter output are both supplied to a summing node logic block in the coupling data unit. The summing node error output is fed to an error magnitude and phase detector that determines whether the digital signal to be generated is positive or negative. The detector also determines the rate at which the digital pulses, each equivalent to 0.024 milliradian of trunnion angle displacement, shall be generated. The digital pulse train is supplied at the appropriate rate by the

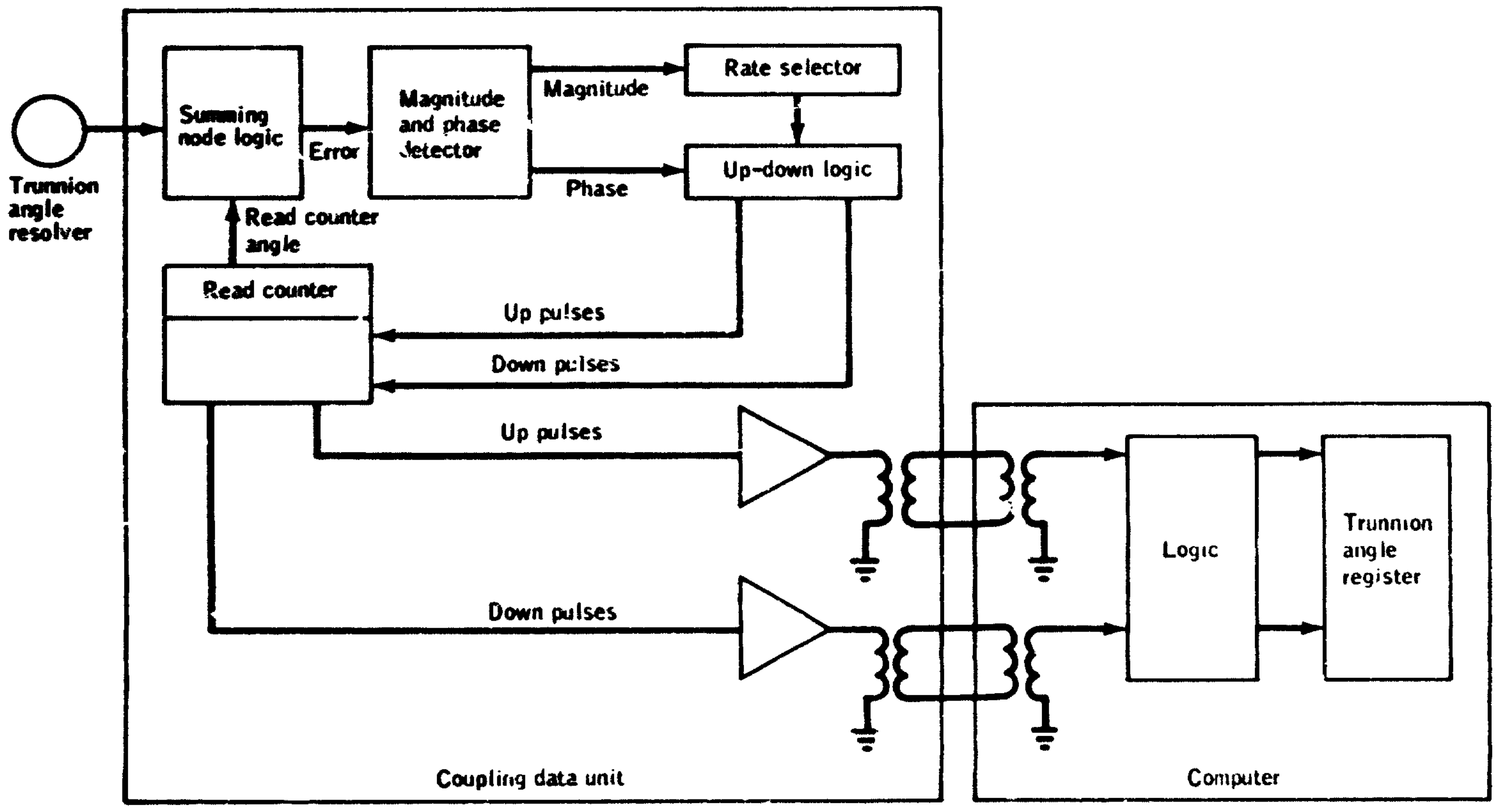


Figure 17-49.- Trunnion resolver signal processing.

rate selector to the up-down logic that in turn selects either an incrementing or decrementing line to feed the pulses to the read counter.

The output of the least significant stage of the read counter supplies trunnion angle change pulses to the command module computer trunnion angle register. Pulses are supplied on two separate lines; one to increase and the other to decrease the contents of the trunnion angle register. Each pulse corresponds to a 0.048 milliradian trunnion angle change.

The coupling data unit and command module computer operated normally during high and low voltage, and high and low temperature tests during postflight testing. The trunnion read counter module was removed from the coupling data unit and operated normally while subjected to thermal cycling, vibration, compression, and flexure tests.

The read counter module is composed of a number of integrated circuits interconnected with a wiring assembly. The wiring assembly is made up of alternate layers of 0.05 millimeter thick ribbon conductors and mylar tape.

The read counter wiring assembly was disassembled, layer by layer, by removing the strips of mylar tape. A 2-centimeter-long segment of enameled copper wire was found included in the third layer of conductors (fig. 17-50). Each end of the wire projected from the side of the wiring assembly immediately adjacent to an interconnecting pin of one of the integrated circuits. When the two wire ends shorted the two different integrated circuit pins, the output of the master flip-flop circuit that multiplies one of the read counter stages was connected to the counter output that feeds the command module computer (fig. 17-49). The master flip-flop then supplied 20-microsecond duration pulses at the rate of 12 800 pulses per second to the read counter computer output (normal pulses are 3 microseconds long and occur at 6400 pulses per second). Tests showed the longer pulses at the higher pulse rate would cause the computer register to change at the 0.698 radian per second rate experienced during the mission.

A short segment of copper wire was inadvertently built into the read counter interconnecting wiring assembly during original manufacturing. The wire segment momentarily shorted together pins on two different integrated circuits, causing the read counter to provide spurious trunnion angle change pulses to the computer.

Acceptance tests performed on the coupling data unit and its components during manufacturing are considered adequate. There is no known non-destructive test which would have detected the presence of the wire segment; therefore, no corrective action can be taken.

This anomaly is closed.

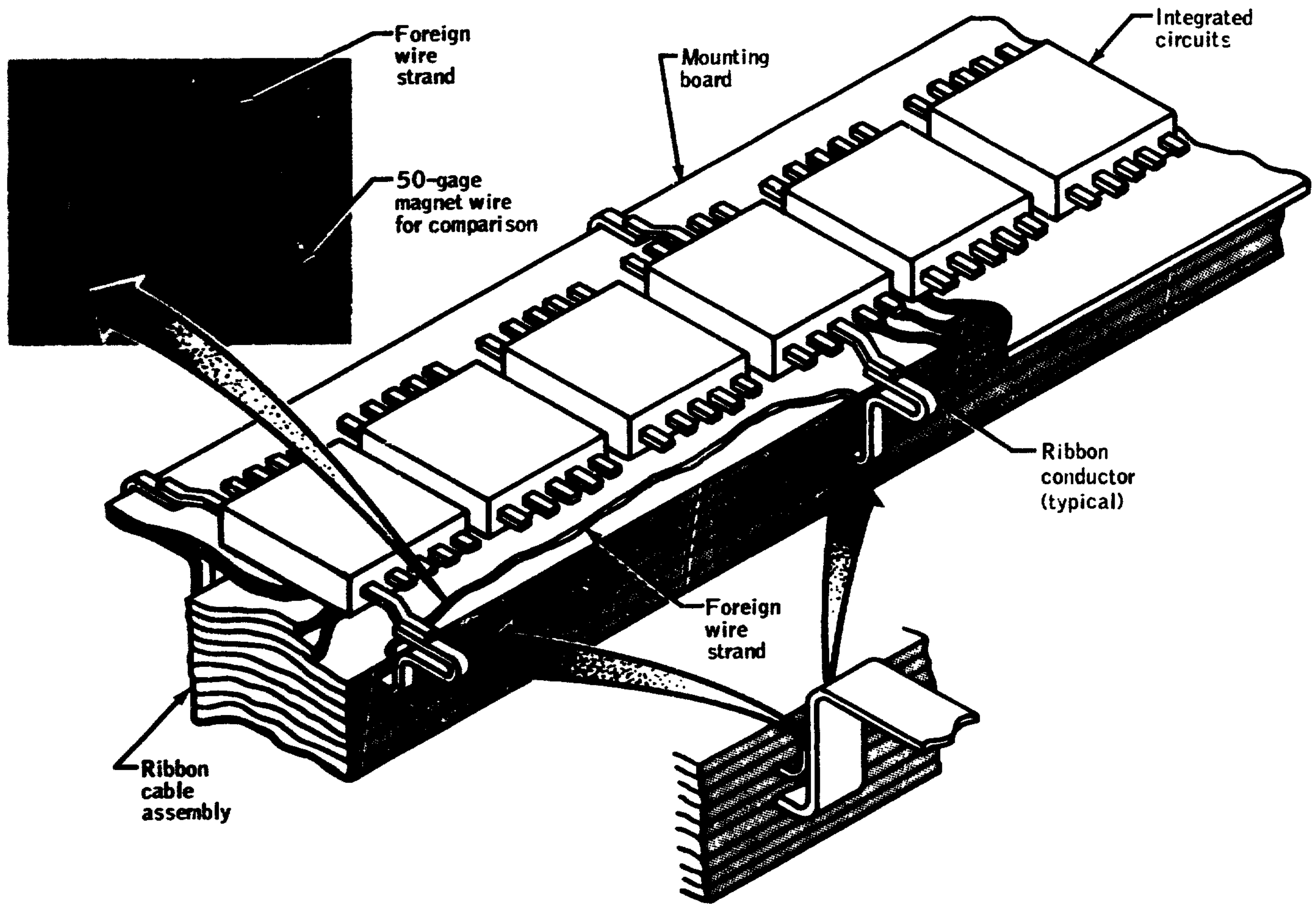


Figure 17-50.- Read counter short circuit.

17.4.2 Experiment M133 (Sleep Monitoring) Recorded Data Noisy and Unusable

Only the first 16 hours of 100 hours of recorded data were usable.

The experiment M133 records brain wave, eye motion and head motion data while the subject sleeps. Two recorders were launched on the Orbital Worskshop and each contained a reel of tape. A third reel of tape was stowed in one of the Orbital Workshop sleep compartment lockers. During the high temperature period prior to the first visit manning, the tape reel stored in the sleep compartment locker reached a temperature of about 332° K. Consequently, a special thermal test of a reel of tape was performed using the flight temperature profile. Data were then recorded on the tape and it was played back. In that case, the first 12 minutes of data were good, and thereafter, the played back data were noisy and unrecoverable. In the ground test and in the flight experiment the degraded portion of the tape was located closest to the center of the supply spool.

Only one of the recorders was used during the first visit manning. Both recorders were used during the second visit. Recordings made during the second visit, using the recorder that was used on the first visit and using resupplied tape, were again noisy and unusable. However, recordings made with the recorder that was not used during the first visit provided high quality data.

Two problems may exist. First, the tape returned from the first manning may have been degraded by the high temperatures that occurred before the first manning. Second, the tape recorder that produced the noisy tape may have experienced some failure.

More tape was resupplied on the third visit manning. In addition, the recorder that produced the noisy recordings during the first and second visit mannings will not be used during the third visit manning.

This anomaly is closed.

18.0 CONCLUSIONS

1. The ability of the crew to correct systems difficulties by actions such as deployment of the twin-pole sunshield, replacement of the rate gyro package, repair of the teleprinter, and repair of the Apollo Telescope Mount experiment door enabled the second visit to proceed as planned, again demonstrating the advantage of having man on board the vehicle.

2. Revisits provide the opportunity to correct hardware problems, restructure objectives, and revise replaceable commodities based on actual experience.

3. Phychological and physical conditions resulting from the 59-day visit indicated no constraints for longer duration flights.

4. Ordinary hand tools could have been used effectively in place of special tools in the zero-g environment when making repairs and adjustments.

5. The limitations of non-continuous ground station coverage imposes restrictions on data return, systems management, and uplink information.

6. The skills learned in underwater training are almost identical to the skills used in actual performance of tasks during an extravehicular activity and, if instructions are adequate, a crewman can perform extravehicular tasks for which he has not specifically trained. Tasks are somewhat easier to perform in zero-g than in underwater training.

APPENDIX A - EQUIPMENT DESCRIPTION

This section contains descriptions of items used for the first time on this visit, or which have not been described previously.

A.1 EXERCISERS

Three exercisers were used on the second visit in addition to the bicycle ergometer and were designated as Mark I, Mark II, and Mark III (fig. A-1).

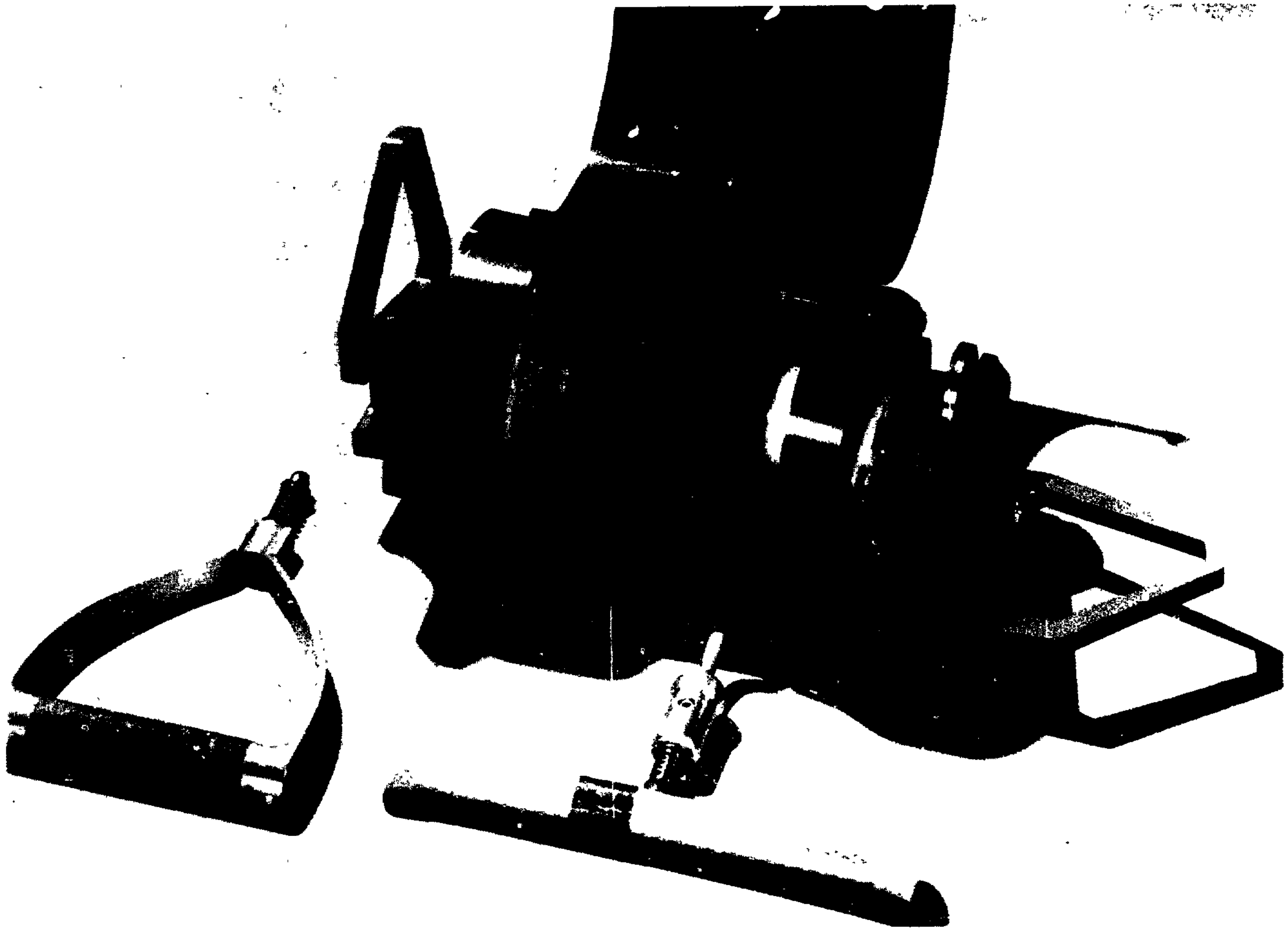
The Mark I exerciser was a modified version of a commercially available device, called the "Mini-Gym," and consisted of a rope wound around a drum. The drum was geared to a centrifugal device which, at a preset speed, pressed against a brake and generated a back force to the rope. In essence, the Mark I exerciser developed a wide range of forces at a virtually constant rate of speed that could be preset. The device was primarily designed for use in exercises of the arm as only one leg could be exercised at a time.

The Mark II exerciser consisted of two aluminum handles between which one to five extension springs could be attached. The force of each spring increased at a rate of approximately 6.7 newtons per meter during extension such that reasonably large forces could be developed. The Mark II exerciser was provided as a backup to the Mark I exerciser.

The Mark III exerciser was a modification of a commercial device called the "Exer-gym." This exerciser consisted of a length of rope which passed through a cylindrical shell containing a capstan. The rope, which had a handle on one end, wound around the capstan and the number of turns could be varied. By manipulating the free end of the rope, relatively constant or widely varying forces could be applied to the handle. Three such devices were on Skylab and have been part of every Apollo and Skylab flight.

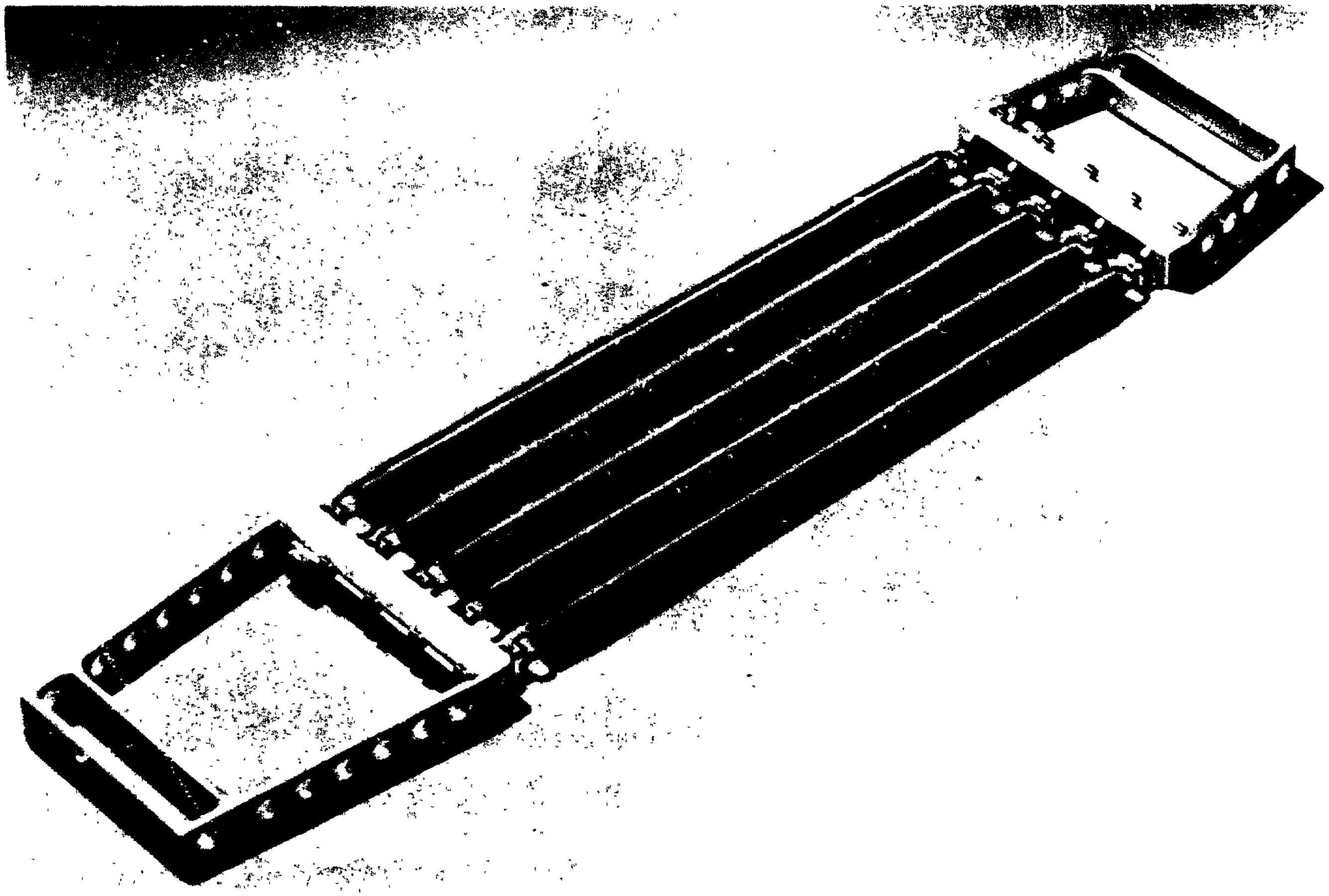
A.2 POLAROID SX-70 CAMERA

The Polaroid camera was basically a commercial Polaroid camera model SX-70 with the leather covering removed. The camera was a medium format motor-driven still camera provided for photography of the Apollo Telescope Mount television displays (solar coronagraph and extreme ultraviolet monitor).



(a) Dynamic exerciser (Mark I)

Figure A-1.- Inflight exercisers.



(b) Chest exerciser (Mark II)

Figure A-1.- Continued.

(c) Exergym (Mark III)

Figure A-1.- Concluded.

The film pack used with the camera contained 10 self-developing color pictures and a battery which provided power for the camera. The film pack and battery were discarded after 10 exposures and a new pack was installed.

Figure A-2 shows the camera, the extreme ultraviolet monitor adapter assembly, remote control switch, closeup lens, and a persistent image scope discussed in the next paragraph. Figure A-3 shows the camera in the operational configuration.

A.3 PERSISTENT IMAGE SCOPE

The persistent image scope was an optical imaging system designed for low light levels. The phosphorus of the tube was selected to provide a slow decay of the image. The scope could be mounted on the extreme ultraviolet monitor bracket, and was used with the extreme ultraviolet monitor to provide a persistent image of the monitor display. The unit was powered by two alkaline "C" size batteries that were replaceable in flight.

A.4 STABILIZED IMAGE BINOCULAR

The stabilized image binocular provided the capability to negate the effects of vibration when binocular viewing was required. Either 10X or 20X magnification could be selected. A magnetic precessor provided a perfectly stable image while tracking targets at an angular slew rate of up to 0.087 radian per second.

The binocular was completely self-contained in that there were no external power supplies, lens attachments, or special mounts. The stabilizing optical element was an integral part of the inertial reference system. The reference element was balanced in all planes, allowing the instrument to be used in any position. Figure A-4 shows the binocular.

A.5 DIGITAL MULTIMETER KIT

A digital multimeter kit was provided for use by the crew to monitor circuits and troubleshoot electrical systems. The kit consisted of an off-the-shelf solid state digital multimeter and a non-inflammable cover which remained in place during operation of the multimeter. A pocket on the side of the cover contained one set of leads and one tethered jeweler's screwdriver.

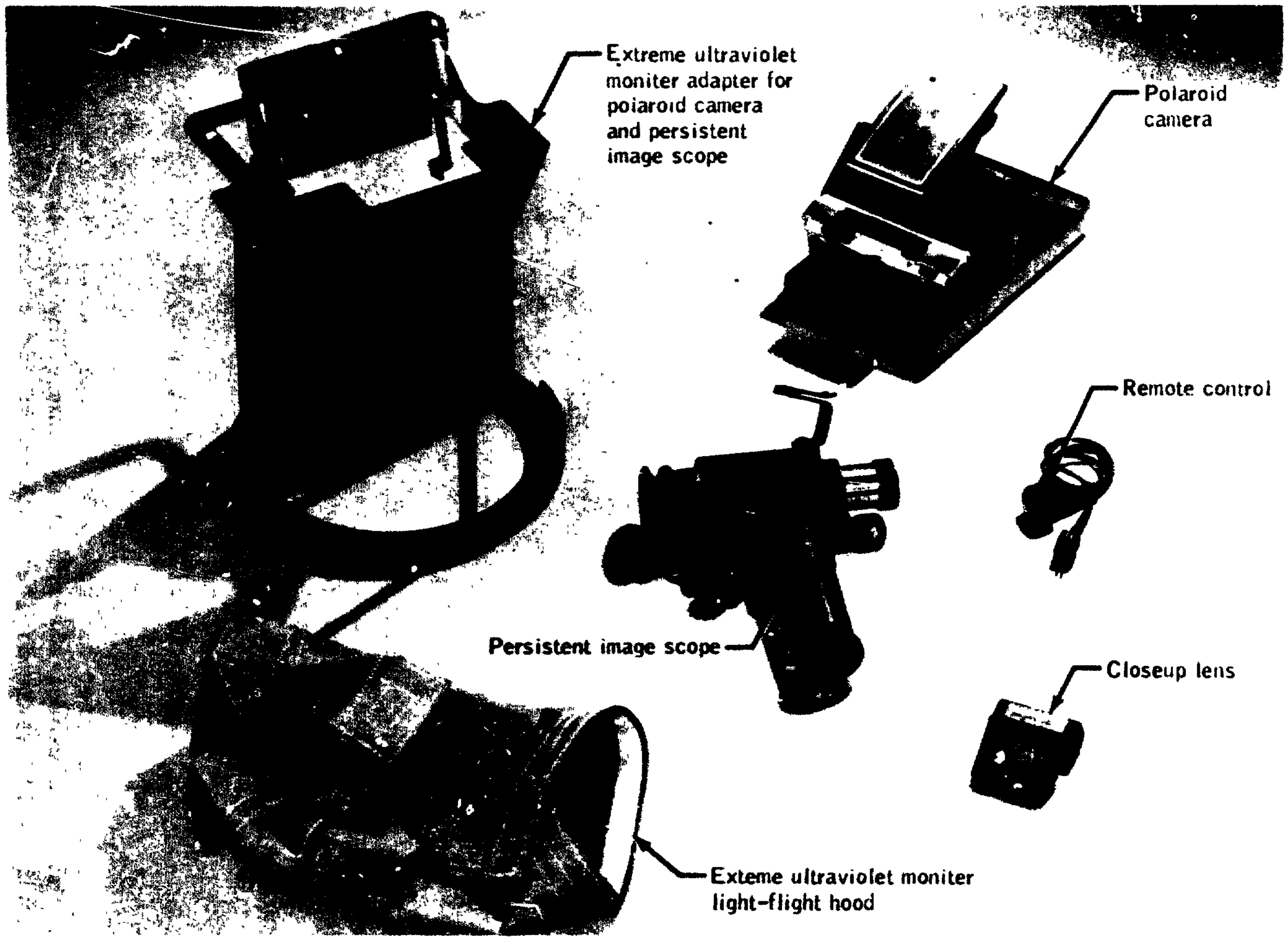


Figure A-2.- Polaroid camera and associated equipment.

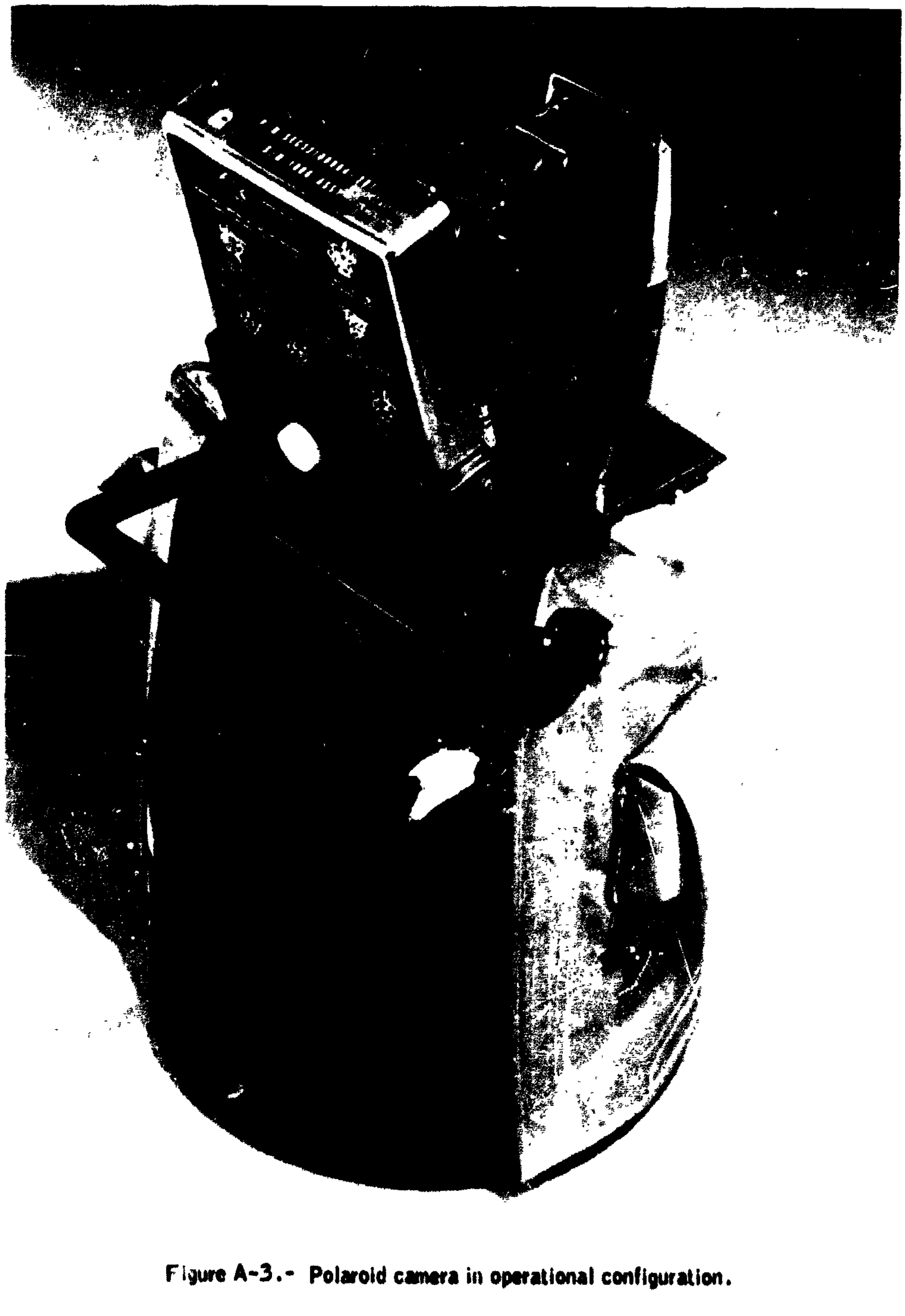


Figure A-3.- Polaroid camera in operational configuration.

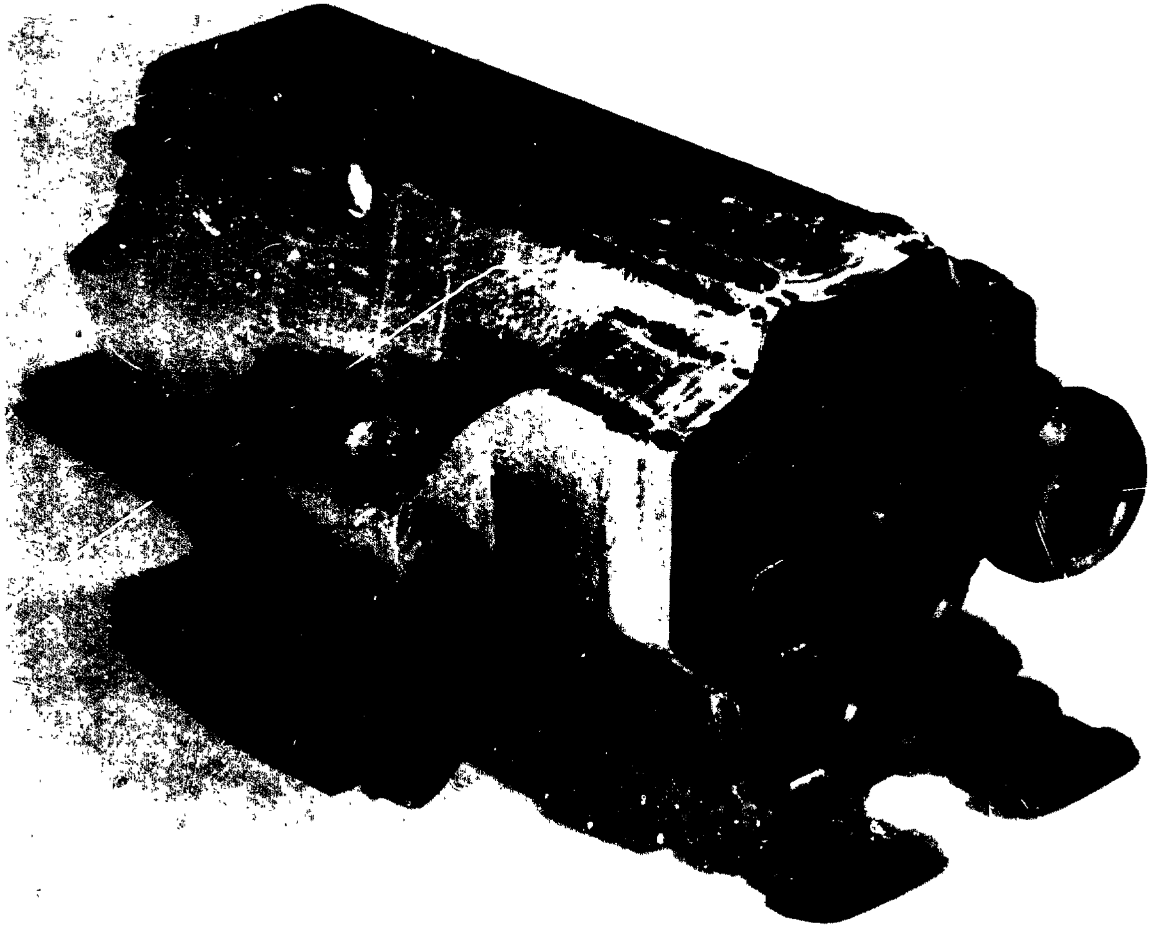


Figure A-4.- Stabilized image binocular.

The digital multimeter incorporated 20 scales of measurement which ranged from 0 to 1000 volts ac/dc, 0 to 2.0 milliamperes ac/dc, and 0 to 20 megohms. The multimeter was powered by four alkaline "C" size batteries. Additional batteries were available from the tape recorder battery supply in the Orbital Workshop off-duty activities equipment.

A.6 HAND-HELD MICROPHONE

The hand-held microphone assembly consisted of a microphone connected to a lightweight headset amplifier through a 4.5-meter twisted shielded cable. The assembly was provided to overcome a problem experienced on the first visit wherein proper distance and orientation could not be maintained when the lightweight headset was used as a hand-held microphone to voice anotate the video tape recorder.

A.7 ARTICULATED MIRROR SYSTEM ADAPTER FLANGE

The articulated mirror system adapter flange was provided to permit the articulated mirror system for experiments S063 (Ultraviolet Airglow Horizon Photography) and S019 (Ultraviolet Stellar Astronomy) to be used in accomplishing the airglow photography objectives. The adapter flange was aluminum and provided a sealed interface between the articulated mirror system and the experiment S063 scientific airlock window. This configuration allowed experiment operation from the anti-solar scientific airlock.

A.8 EXTRAVEHICULAR ACTIVITY BRACKET ASSEMBLY FOR EXPERIMENT S149

The extravehicular activity bracket assembly allowed experiment S149 (Particle Collection) to be mounted to the Apollo Telescope Mount for data collection. One end of the bracket interfaced with the experiment cassettes while the other was attached to the Apollo Telescope Mount rim. The cassettes were attached to the bracket and manually deployed and retrieved by the crew.

A.9 DOCKING PROBE MODIFICATION

The emergency docking procedure implemented during the first Skylab visit, required depressurizing the cabin, removing the command module forward hatch, and manually removing the probe pyrotechnic cover so that the probe could be retracted with the capture latches in the cocked position.

For the second visit, the pyrotechnic cover was modified by replacing the built-in capture latch release handle with an alignment bushing so the probe could be retracted with the capture latches in the cocked position without the preliminary procedural steps required on the first visit.

A new removable capture latch unlocking tool was provided for the second visit to replace the deleted built-in release handle. The tool's function was to release the probe capture latches for probe removal and for normal transfer through the tunnel.

APPENDIX B - SPACECRAFT HISTORY

The history of command and service module (CSM-117) operations at the manufacturer's facility, Downey, California, is shown in figure B-1, and the operations at Kennedy Space Center, Florida, is shown in figure B-2.

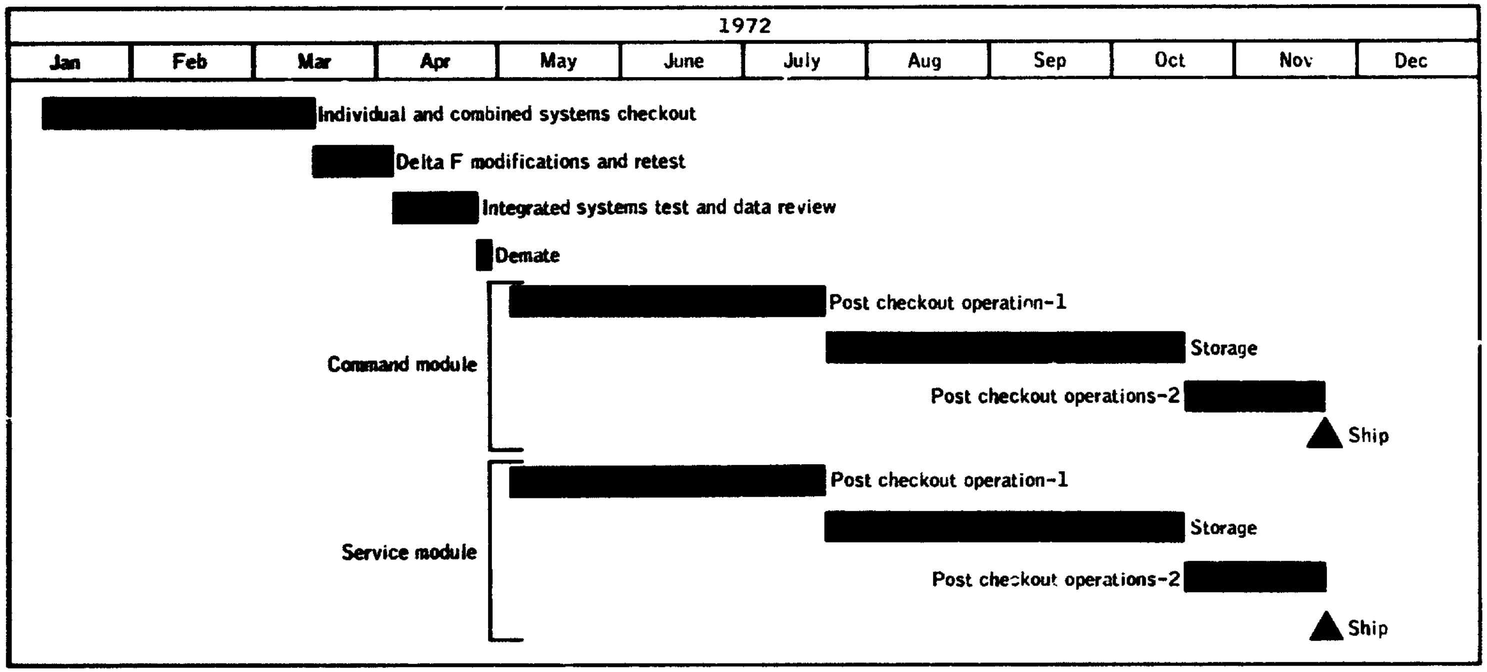


Figure B-1.- Second visit command and service module (117) history at Contractor facility.

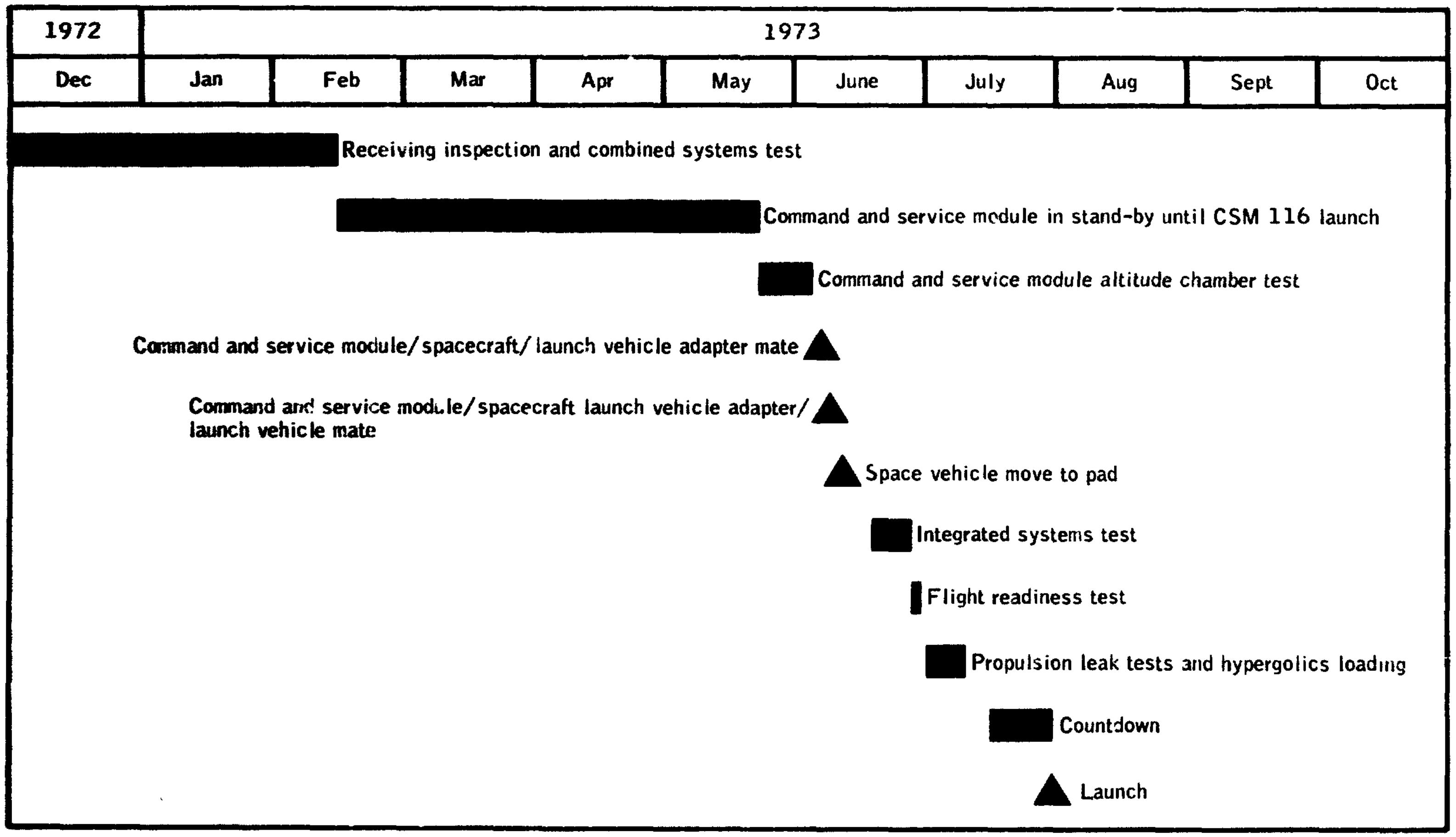


Figure B-2.- Second visit command and service module (117) history at Kennedy Space Center.

APPENDIX C - POSTFLIGHT TESTING

Postflight testing and inspection of the command module and crew equipment for evaluation of the inflight performance and investigation of flight problems were conducted at the contractor's and vendors facilities and at the Johnson Space Center in accordance with approved Spacecraft Hardware Utilization Requests (SHUR's). The tests performed as a result of inflight problems are described in table C-1 and discussed in the appropriate systems performance section of this report. Tests being conducted for other purposes in accordance with other SHUR's and the basic contract are not included.

TABLE C-I.- POSTFLIGHT TESTING SUMMARY

SHUR number	Purpose	Test performed	Results
		Environmental Control	
117010	Determine cause of water/glycol leak.	Perform leak test of primary water/glycol system, plus tear-down and analysis.	Leaking suit heat exchanger primary water/glycol valve caused by valve shaft porosity and contamination under "O" rings.
		Reaction Control	
117007	Determine if any abnormal conditions present on command module reaction control system engine dynatube connectors which could assist in explaining the service module reaction control system quad D leak.	Measure connector torques and disassemble and inspect.	No abnormal conditions found.
		Communications	
117014	Investigate cause for continuously keyed VHF communications during recovery	Operate system in configuration.	Normal operation. Continuous keyed operation caused by saltwater shorting the docking ring connector pins after landing.
117003	Determine cause for data storage equipment rewinding when updata link stop command was sent.	Remove updata link and data storage equipment and perform bench tests. X-ray suspect diodes and relays, and checkout spacecraft wiring.	Normal operation of units. X-ray revealed loose solder ball in relay.
117005	Investigate television camera cable failure.	Perform resistance check.	Open coaxial conductor.
		Instrumentation	
117006	Determine cause for erratic operation of reaction control system helium manifold pressure measurement.	Perform continuity check and perform failure analysis of transducer.	No failed component found. Erratic operation resulted following exposure to electromagnetic interference source.
		Crew Equipment	
117004	Investigate reported leak in Commander's liquid cooled garment.	Perform leak test with water and nitrogen.	No leak found.

APPENDIX D - MASS PROPERTIES

Mass properties for the second visit are summarized in table D-I. These data represent the conditions as determined from analyses of expendable loadings and usage. Variations in the command and service module and Saturn Workshop mass properties are determined for each significant mission phase from lift-off through landing. Expendable usage are based on reported real-time data. The weights and centers-of-gravity of the individual modules were measured prior to flight and inertia values calculated. All changes incorporated after the actual weighing were monitored, and the mass properties were updated.

TABLE D-I.- MASS PROPERTIES

Event	Weight, kg	Center of gravity, cm			Moment of inertia, kg m			Product of inertia, kg m		
		X	Y	Z	I_{XX}	I_{YY}	I_{ZZ}	P_{XY}	P_{XZ}	P_{YZ}
Saturn Workshop - First Visit										
Lift-off	89 095.5	8361.9	-4.3	7.9	548 296	6 008 545	6 042 229	-13 4[illegible]2	4 452	17 63[illegible]
[a]In orbit	75 687.3	8256.5	0.7	12.1	426 704	4 634 993	4 606 736	-55 786	-4 208	1[illegible] 680
At first docking	74 773	-816.6	-0.4	76.0	815 622	3 806 862	3 566 693	59 805	538 23[illegible]	13 787
At first undocking	74 428	-815.8	-9.8	76.5	892 442	3 773 920	3 614 293	70 1[illegible]8	526 226	26 389
Second Visit										
Lift-off	20 124	2549.16	6.19	3.88	38 722	532 878	533 8[illegible]	-3 970	2 026	-1 7[illegible]2
Initial orbit achieved	14 168	2446.04	8.20	4.54	24 150	71 607	7[illegible] 673	-1 870	1 241	-1 727
Coelliptic orbit	13 486	2457.67	7.23	4.72	22 997	67 402	67 680	-1 560	1 225	-1 774
Rendezvous complete	13 224	2459.78	6.78	6.01	22 486	66 767	67 026	-1 [illegible]87	1 063	-1 596
Command and service module at docking	13 211	627.45	2.00	-8.89	22 464	6[illegible] 331	68 408	1 822	17	417
Saturn Workshop at docking	74 391	-815.54	-9.52	76.70	888 669	3 783 661	3 625 384	69 488	526 885	[illegible] 968
Orbital assembly configuration	87 597	-597.89	-7.79	63 80	9.9 485	6 192 132	6 028 861	8[illegible] 989	388 245	27 277
Command and service module transfer complete	87 432	-612.64	-7.9[illegible]	64.00	919 224	6 173 927	6 008 183	89 414	396 252	28 323
MSFC sail deployed	87 371	-611.63	-7.74	64.71	919 263	6 175 396	6 011 901	90 045	396 293	28 122
Orbital assembly prior to command and service module separation	86 707	-607.94	-7.71	65.76	904 73[illegible]	6 302 280	6 142 [illegible]65	87 604	384 356	26 478
Saturn Workshop remaining in orbit	73 397	-828.49	-9.19	79.19	872 621	3 870 922	3 716 825	64 869	525 860	27 335
Command and service module at CM/SM separation	12 402	2470.53	6.62	5.02	2[illegible] 222	59 309	59 547	-1 316	1 [illegible]43	-1 [illegible]25
Command module at entry interface	[illegible]932	2638.88	-0.33	14.63	8 106	7 019	6 [illegible]37	54	-598	-30
Command module at drogue mortar firing	5 744	2636.01	-0.30	14.60	7 916	6 597	5 938	56	-564	-30
Command module at landing	5 505	2630.32	-0.33	15.01	7 806	6 118	5 [illegible]54	53	-536	-29

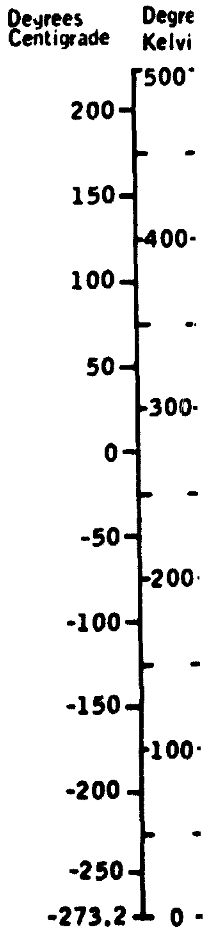
APPENDIX E - CONVERSION DATA

The values shown in this report conform to SI standards. Relationship to conventional units of measurement is shown in figure E-1.

FOLDOUT FRAME

1973 Date		Day of year	Visit Day
July	28	209	1
	29	210	2
	30	211	3
	31	212	4
Aug	1	213	5
	2	214	6
	3	215	7
	4	216	8
	5	217	9
	6	218	10
	7	219	11
	8	220	12
	9	221	13
	10	222	14
	11	223	15
	12	224	16
	13	225	17
	14	226	18
	15	227	19
	16	228	20
	17	229	21
	18	230	22
	19	231	23
	20	232	24
	21	233	25
	22	234	26
	23	235	27
	24	236	28
	25	237	29
	26	238	30
	27	239	31
	28	240	32
	29	241	33
	30	242	34
	31	243	35
Sep	1	244	36
	2	245	37
	3	246	38
	4	247	39
	5	248	40
	6	249	41
	7	250	42
	8	251	43
	9	252	44
	10	253	45
	11	254	46
	12	255	47
	13	256	48
	14	257	49
	15	258	50
	16	259	51
	17	260	52
	18	261	53
	19	262	54
	20	263	55
	21	264	56
	22	265	57
	23	266	58
	24	267	59
	25	268	60

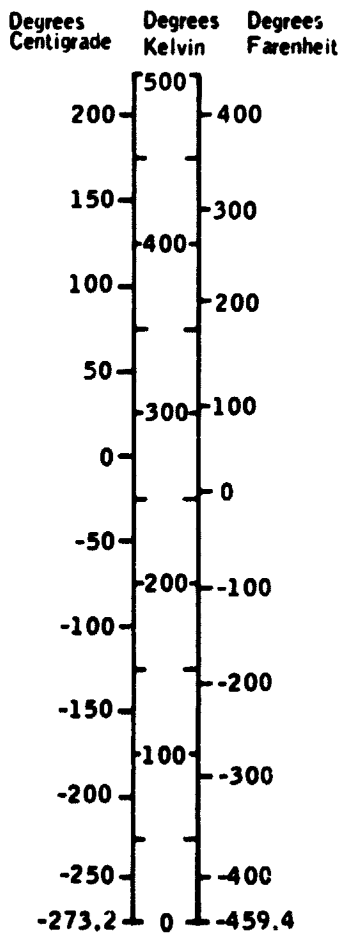
(a) Date conversion



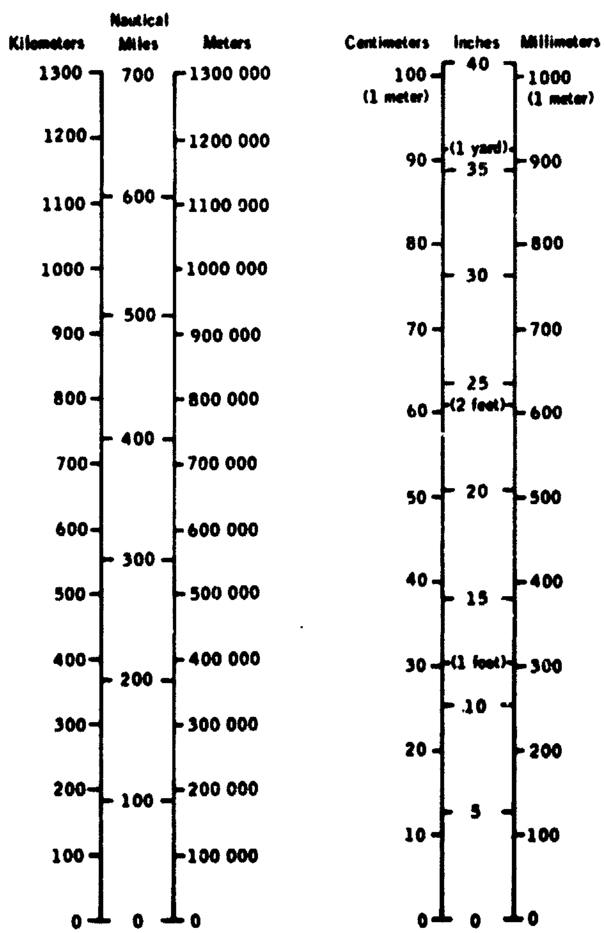
(b) Tempera conver

FOLL UT FRAME

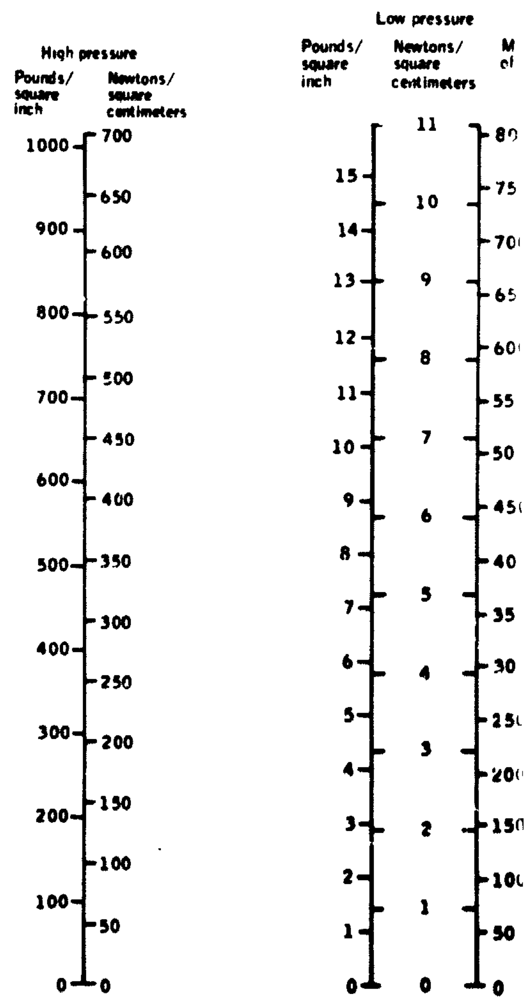
2



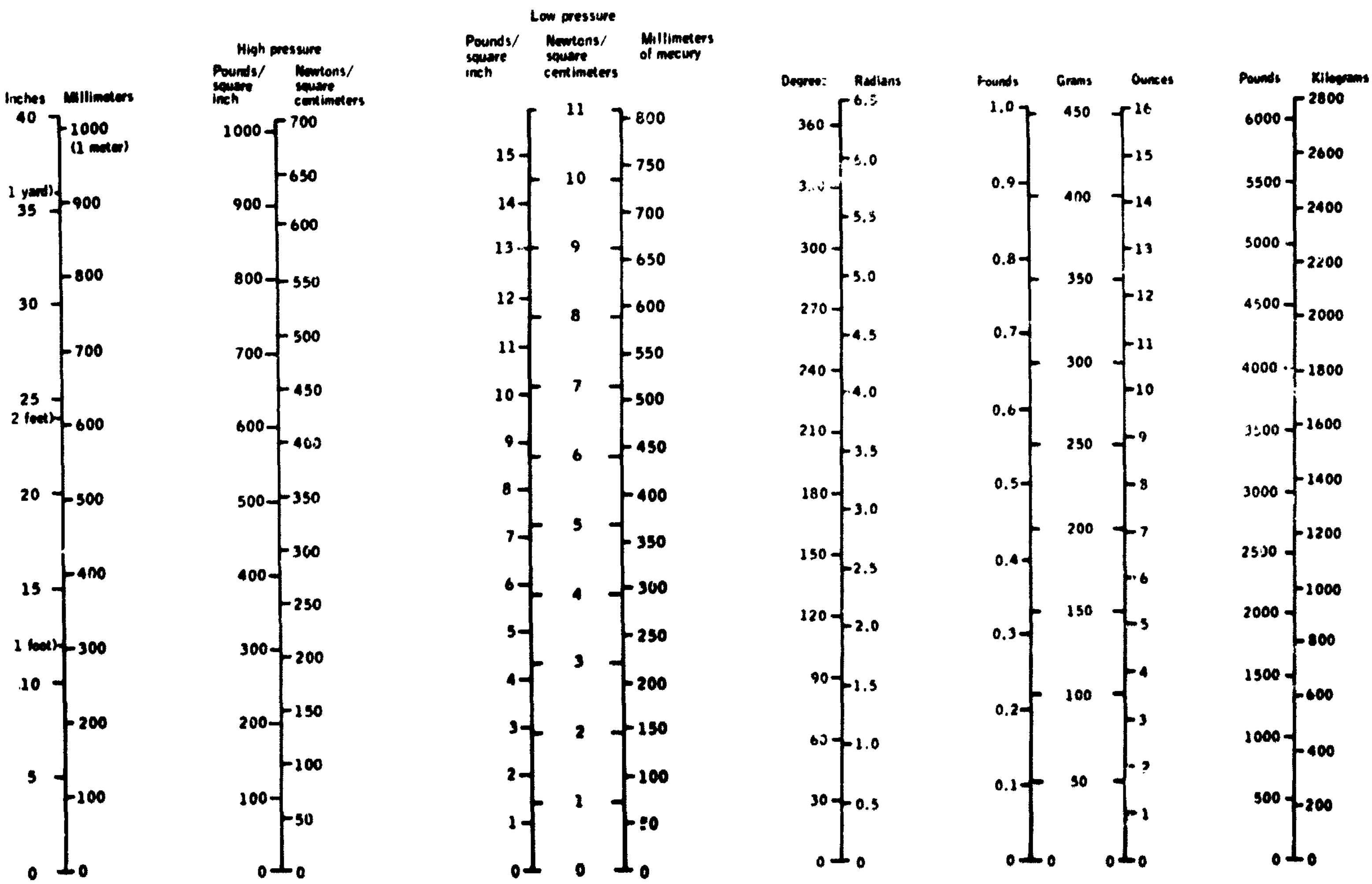
(b) Temperature conversion



(c) Linear measurement conversion



(d) Pressure conversion



'ersion

(d) Pressure conversion

(e) Angular conversion

(f) Mass conversion

Figure E-1.- Conversion data.

APPENDIX F - GLOSSARY

Accomodation	Adjustment of the eye for various distances.
Aldosterone	A steroid hormone secreted from the adrenal cortex.
Bacitracin	An antibacterial polypeptide active against hemolytic *streptococci*, *staphylococci*, and several types of Gram-positive aerobic, rod-shaped organisms.
Binocular stereoscopic acuity	Ability to see objects in three dimensions.
Biocide	An agent destructive to living organisms.
Cariogenic	The process of decay in teeth.
Cerenkov radiation	Polarized light produced by particles traversing a solid or liquid medium having an index of refraction greater than one at a speed greater than that of light in the same medium.
Chloral hydrate	A hypnotic sedative and anticonvulsant.
Cirrus	A white filmy variety of cloud in the highest cloud region, usually consisting of minute ice crystals.
Cortisone	A potent hormonal substance influencing the biochemical behavior of most, if not all, tissues of the body. Its therapeutic action is due to the pharmacological effects of hormonal excess.
Dermatologic	Relating to the skin and skin diseases.
Dextroamphetamine	A compound used as a central nervous system stimulant.
Distal	Farthest from the midline or trunk.
Enteric	Pertaining to the intestines.
Enterobacter	A genus of bacteria which includes many animal parasites, some plant parasites, and frequently occur as saprophytes which decompose carbohydrate-containing plant materials.

Emollient	An agent which softens or soothes irritation in skin or mucous membrane.
Epinepherine	Adrenalin; a most potent stimulant.
Fissure	A longitudinal opening or groove.
Footprint	Outline of the predicted landing area.
Glutathione	A coenzyme of gyoxalase. It appears to be a ubiquitous reducing agent, involved in many oxidation-reduction reactions.
Hematocrit	a. A centrifuge or device for separating the cells and other particulate elements of the blood from the plasma. b. The volume of erythrocytes packed by centrifugation in a given volume which consists of erythrocytes or as the volume in cubic centimeters of erythrocytes packed by centrifugation of blood.
Hemoglobin	The iron containing pigment of the red blood cells. Its function is to carry oxygen from the lungs to the tissues.
Humoral	Pertaining to body fluids or substances contained in them.
Immunoglobulins	A group of protein molecules important to the body's immunologic system.
Immunology	The science dealing with the various phenomena of immunity, induced sensitivity, and allergy.
In vitro	In glass, as a test tube.
Intraocular	Within the eyeball.
Isokinetic	Equal motion.
Isolation	(Microbiology): The successive propogation of a growth of microorganisms until a pure culture is obtained.

Isotope injection	Injection of one of two or more nuclides that are chemically identical but differ in mass number. (Radioactive isotopes have an unstable nuclear composition and decompose spontaneously by emission of a nuclear electron, thus achieving a stable nuclear composition. Radioactive isotopes are widely used in medicine as tracers.)
Klebsiella pneumoniae	A microorganism causing a severe form of pneumonia.
Lumbar	The last five vertebrae or pertaining to the loins.
Lysozyme	An enzyme with antibacterial activity that is present in saliva, tears and other body fluids.
Malaise	A vague feeling of body discomfort, uneasiness or indisposition, often indicative of infection.
Mycological	Relating to fungi.
Near point of convergence	Coordinated movement of both eyes towards fixation of the same near point.
Neomycin	An antibacterial substance active against a variety of gram-positive and gram-negative bacteria.
Neutrophil(e)	a. Staining easily with neutral dyes. b. A leucocyte which stains easily with neutral dyes.
Norepinephrine	A hormone produced by the adrenal medulla. It is chiefly a vasoconstrictor
Oculogyral illusion	The apparent movement of an image in space in the same direction as that in which one seems to be turning when the semicircular canals are stimulated.
Organoleptic	Stimulating any of the organs of sensation.
Orthostatic	Relating to or caused by erect posture.
Osmotic fragility of the blood	Increased susceptibility of the blood cells to break down when the proportion of the saline content of the fluid is altered.

Oxymetazoline hydrochloride	A vaso constrictor used topically to reduce swelling and congestion of the nasal mucosa.
Paresthesia	An abnormal spontaneous sensation such as numbness, burning, pricking, etc.
Polymyxin	A mixture of antibiotic substances obtained from cultures of *Bacillus polymyxa*, a microorganism found in water and soils.
PR internal	The period of time between the onset of atrial excitation and the onset of ventricular excitation.
Presyncopal	The state immediately preceding a brief loss of consciousness associated with transient cerebral anemia.
Prochlorperazine	A tranquilizer, used in the treatment of anxiety and tension and to combat nausea and vomiting.
Pseudomonas aerugenosa	A microorganism causing certain antibiotic resistant secondary infections.
QRS vector	Direction and magnitude of the Q, R, and S points or deflection of an electrocardiogram representing cardiovascular contraction.
Rad	A unit of absorbed dose of ionizing radiation equal to an energy of 0.01 joules/kilogram of irradiated material.
Radius	The lateral and shorter of the two bones of the forearm.
REM	Rapid eye movement in a stage of sleep.
Rem	A radiation biological effectiveness factor of biological injury to human tissue for any dose of ionized radiation equivalent to one roentgen of X-ray or gamma ray.
Scopolamine	An alkaloid found in the leaves and seeds of *Hyoscyamus niger* and used as a sedative.
Secobarbital	A sedative and short-acting hypnotic.
Serum complement factor C_3	One of the factors involved in the reaction of antibiotic and thought to be the most important factor for activation of immune response.

Staphylococcus aureus	A microorganism causing boils and other skin lesions.
Sternum	The breastbone.
Streptococcus	A genus of bacteria of which there are many types.
Ulna	Elbow bone; the medial and larger of the two bones of the forearm.
Venipuncture	Puncture of a vein for any purpose.
Vestibular	Pertaining to a small space or cavity at the entrance to a canal.
Virological	Relating to viruses and virus deseases.
Visceral	Stomach intestinal awareness.

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